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Relationships Among Stress, Blood Pressure, and Heart Rate Variability in Meditators

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RELATIONSHIPS AMONG STRESS, BLOOD PRESUURE

AND HEART RATE VARIABILITY IN MEDITATORS

A dissertation submitted in partial fulfillment of the requirements for the degree of
Doctor of Philosophy at Virginia Commonwealth University.

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Abstract

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AND HEART RATE VARIABILITY IN MEDITATORS

By Sangthong Terathongkum, Ph.D., RN

A Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University.

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PROBLEM STATEMENT: Growing evidence indicates that psychological stress contributes to cardiovascular diseases through complex neuroendocrine mechanisms. Psychological stress leads to several physiological responses including increased heart rate (HR) and blood pressure (BP) as well as decreased heart rate variability (HRV) through alterations in the autonomic nervous system (ANS), specifically increased sympathetic nervous system (SNS) activity and decreased parasympathetic nervous system (PNS) activity. Meditation is thought to induce an innate relaxation response leading to reduced psychological stress. Findings from past studies have provided inconclusive evidence regarding the direction and strength of relationships among stress, BP, HRV, and meditation practice. PROCEDURES: A cross-sectional descriptive-correlational design was used to examine relationships among perceived stress, BP, HRV and meditation practice in meditators. A convenience sample of 71 meditators at two meditation centers in the southeast United States was used. Sample size was based on a power analysis. Each participant was asked to complete meditation, perceived stress, and demographic questionnaires. Participants' BP was measured before meditation and HRV was recorded during a 30 minute meditation session. Finally, BP was recorded after meditation. RESULTS: Participants were predominantly female (55%), Caucasian/white (94%), and Buddhist (76%), with 93% having at least college graduate. Most participants practiced soto zen or vipassana meditation (45% and 30%, respectively). The average length of total meditation practice was 103.66 months. Participants practiced meditation an average of once a day for 4 days a week with mean session duration of 34 minutes. Most participants had a low level of perceived stress and normal HRV. There was a statistically significant decrease in mean systolic BP after meditation ($t = 5.31$, $p < .0001$) and a significant inverse relationship between the length of total meditation practice and perceived current stress. However, there were no statistically significant relationships among meditation practice, perceived stress and the ANS assessed through BP and HRV. CONCLUSIONS: The results suggested meditators had low levels of perceived stress and that meditation had an effect on systolic BP and perceived current stress. Future research needs to include longitudinal studies to elucidate the cumulative effects of consistent meditation practice on psychological and physiological outcomes.

Chapter 1

Introduction

Growing evidence indicates that psychological stress contributes to cardiovascular diseases through complex neuroendocrine mechanisms (Papousek, Schulter, & Premsberger, 2002; Walton, Schneider, & Nidich, 2004). Psychological stress leads to several physiological responses including increased heart rate (HR) and blood pressure (BP) as well as decreased heart rate variability (HRV) through alterations in the autonomic nervous system (ANS), specifically increased sympathetic nervous system (SNS) activity and decreased parasympathetic nervous system (PNS) activity (Furlan et al., 2000; Hjortskov et al., 2004; Kang et al., 2004; Kawachi, Sparrow, Vakonas, & Weiss, 1995; MacArthur & MacArthur, 2000; Witek-Janusek & Werner, 2000). These changes, if persistent, can contribute to the development of a variety of cardiovascular diseases.

Approaches to management of psychological stress have been developed with the goal of reducing stress, thus eliminating adverse physiological responses. Meditation is one approach to stress management which, according to current understandings of physiology, may induce a positive parasympathetic state and counteract increased sympathetic activity, thereby reducing HR and BP as well as increasing HRV (Benson, 1975; Benson, 1993; Bogart, 1991; Goleman & Schwartz, 1976; Lehmann & Benson, 1982; Matzner, 2003; Peng et al., 1999; Peng et al., 2004). The focus of this study was to evaluate the relationships among meditation practice, perceived stress and activity of the ANS as indicated by BP and HRV in meditators.

Psychological stress is viewed by Lazarus and Folkman (1984) as a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being. Viewing psychological stress in this manner, two critical processes, cognitive appraisal and coping, mediate the person-environment relationships. Cognitive appraisal is an evaluative process that determines why and to what extent a particular transaction between the person and the environment is assessed as psychological stress. Coping is the process through which the individual manages the demands that are appraised as stressors (Lazarus & Folkman, 1984). Thus, results of psychological stress without effective coping processes can be physiological and psychological problems. High levels of psychological stress have been associated with minor illnesses like insomnia, backache, or headache, and can contribute to potentially life-threatening diseases such as high BP and heart disease (Kral et al., 1997; Pelletier, 1993; Vrijkotte, van Doornen, & de Geus, 2000).

In order to account for the association between psychological stress and physical illness, the physiological effects of stress have been studied. Psychological stress appears to affect the balance within the ANS, which is the primary regulator of neural homeostasis. The regulation of HR, HRV and BP are all moderated through neural homeostatic processes. Stimulation of the SNS ultimately leads to an increase in BP and HR with a decrease in HRV while activation of the PNS leads to decreased BP and HR along with increased HRV (Hjortskov et al., 2004; Verklan & Padhye, 2004; Witek-Janusek & Werner, 2000).

Heart rate variability is a sensitive index of ANS activity and can be measured simply and noninvasively. It is commonly defined as the change in the time interval between heartbeats, from beat to beat (Kang et al., 2004; MacArthur & MacArthur, 2000; Vrijkotte et al., 2000). Heart rate variability is a measurement of the interactions within the ANS and reflects all physiological factors regulating the normal rhythm of the heart (Kang et al., 2004). In normal adults, higher HRV is viewed as desirable, providing sensitive responsiveness and capacity for responding to changing physiological signals. Generally, persons with high level of stress have been noted to have a decreased HRV as a result of sympathetic overactivity (Kang et al., 2004; MacArthur & MacArthur, 2000).

Power spectral analysis of HRV has been used to quantify power spectral densities at different frequencies of HRV in order to delineate parasympathetic from sympathetic components of the ANS (Cowan, Kogan, Msee, Hendershot, & Buchanan, 1990; Sato et al., 1998; Schuit et al., 1999; Verklan & Padhye, 2004; Vrijkotte et al., 2000). In humans, power spectral analysis of HRV has two major components: low frequency component of HRV (LF) and high frequency component of HRV (HF). The LF power reflects both parasympathetic and sympathetic activity whereas the HF power has been shown to correspond to parasympathetic activity, which reflects the maintenance of physiological homeostasis and reactivity of the SNS activity (Cowan et al., 1990; Sato et al., 1998; Verklan & Padhye, 2004). Studies were reported indicating that LF power has been positively associated with psychological stress and BP, but HF power has been negatively correlated with both psychological stress and BP (Furlan et al., 2000; Hjortskov et al., 2004; Papousek et al., 2002; Sato et al., 1998; Schuit et al., 1999; Sloan et al., 1996; Vrijkotte et al., 2000). That is, when LF power is increased and HF power is decreased, an individual is more likely to have a high level of psychological stress and/or an elevated BP.

Changes in both BP and HRV, as indicators of ANS activity, have not been conclusively documented in those who meditate. Meditation refers to a specific consciousness state in which deep relaxation and increased internalized attention coexist (Murata et al., 2004). Meditation is also thought to induce an innate relaxation response leading to reduced psychological stress (Astin, 1997; Benson, 1975; Chang et al., 2004; Goleman & Schwartz, 1976; Shapiro, Schwartz, & Bonner, 1998; Waelde, Thompson, & Gallagher-Thommpson, 2004). Meditation can be also considered a type of healing intervention which assists an individual to enhance wellness and well-being. This modality stimulates inherent healing capacities, which induce recovery and repair mechanisms. Healing interventions can be physical (acupuncture, exercise and manipulation), psychological (counseling, psychotherapy and meditation), or energetic (tai chi, qigong, and yoga) (Jonas & Chez, 2003). Thus, meditation as a psychological healing intervention is a stress management technique which may be used to alter psychological and physiological responses to stressful events or stressors appraised as psychological stress, and to improve stress-related symptoms (Caudell, 2000; Peng et al., 1999; Shapiro & Giber, 1978).

Purpose and Research Hypotheses

The purpose of this study was to examine the relationships among perceived stress, BP, HRV and meditation practice in meditators. The overall goals of this study were to evaluate the relationships between perceived stress and reactivity of the ANS assessed through BP and HRV, as well as the relationships between meditation practice and perceived stress and reactivity of the ANS assessed through BP and HRV. It was hypothesized that: (1) perceived stress had a positive correlation with BP and LF power, and an inverse correlation with HF power in meditators; and (2) meditation practice had a negative correlation with perceived stress, BP, and LF power, and a positive correlation with HF power in meditators.

Background

The variables of interest in this study were psychological stress, BP, HRV, and meditation. Each of these variables is described and a theoretical definition is provided in the following sections.

Psychological Stress

Most contemporary approaches to the study of stress have been influenced by three different stress theories. These include stress as a response by Selye, stress as a stimulus by Holmes, Rahe, and Masuda, and stress as a transaction by Lazarus and Folkman (Witek-Janusek & Werner, 2000). To provide a historical context, views of Selye and Holmes, Rahe and Masuda are reviewed. The stress framework guiding this study, however, is that of Lazarus and Folkman (1984).

Stress as a response. Selye (1993) defined stress as the nonspecific responses of any demand upon the body. Selye viewed stress-inducing demands as stressors. Stressors can be physical or emotional and pleasant or unpleasant. Responses to stressors induce physiological changes, involving nervous, endocrine, and immune system. Selye termed these responses “the general adaptation syndrome (GAS).”

The GAS consists of three stages, including alarm reaction, resistance, and exhaustion. The alarm reaction occurs when an individual perceives a stressor physically or mentally, and the fight-or-flight response is initiated. Physical signs and symptoms of this stage include increased BP, HR, and respiration rate. Then, the individual quickly moves to the stage of resistance to stressors. The amount of resistance to the stressors depends on the level of physical functioning, coping abilities, and number of stressors. Adaptation may occur at this time. If not, the individual may move to the stage of exhaustion. This occurs when all energy for adaptation has been expended. The individual in this stage usually becomes ill and may die if assistance from an external source is not available (Selye, 1993; Witek-Janusek & Werner, 2000). However, the GAS does not occur in response to all demands or stressors such as a pleasant stress (Cohen, Kessler, & Gordon, 1995). Thus, the stress measurements for this theory have been applied in terms of biological perspectives, including stress hormones, cardiovascular responses, and immune responses, whereas psychological stress measurement has not been standardized (Cohen et al., 1995).

Stress as a stimulus. Holmes, Rahe, and Masuda viewed stress as a stimulus that disturbs an individual’s homeostatic balance (Witek-Janusek & Werner, 2000). Their focus was on disturbances related to life changes or life events. A life event is considered to be stressful if it is associated with some demand for individual adaptive or coping behavior (Witek-Janusek & Werner, 2000). This concept was mostly based on Selye's theory that stress responses consisted of non-specific biological changes elicited in response to environment events (Turner & Wheaton, 1995).

Based on their stress concept, Holmes and colleagues developed two questionnaires: the Schedule of Recent Experiences (SRE) (Hawkins, Davies & Holmes, 1957) and the Social Readjustment Rating Scale (SRRS) (Holmes & Rahe, 1967) to assess the effects of life changes on health. These questionnaires numerically weight the stressful impact of various life changes. A greater number of stressful life events occurring during a specific period of time are associated with a greater vulnerability to illness (Witek-Janusek & Werner, 2000).

Stress as a transaction. Lazarus and Folkman's (1984) stress theory focuses on person-environment transactions. Lazarus (1993) indicated that stress is associated with positive and negative emotion. Psychological stress is focused on negative emotion such as anger, anxiety, shame, guilt, and sadness. Lazarus and Folkman (1984) defined psychological stress as a particular relationship between the person and the environment that is appraised by the person as taxing or exceeding his or her resources and endangering his or her well-being. They emphasized the role of cognitive appraisal in assessing stressful situations and selecting coping options. Cognitive appraisal was defined as a process of evaluating a particular encounter with events. Lazarus and Folkman identified three kinds of cognitive appraisal, which included primary, secondary, and reappraisal.

Primary appraisal refers to an evaluation of the situation with regard to its significance for the individual's well-being. An individual may judge an encounter as irrelevant, benign-positive, or stressful. If demands are appraised as psychologically stressful, they can be classified as harm/loss, threat, and challenge. Harm/loss refers to actual damage. Threat means anticipated harm/loss. Challenge refers to a potential for personal gain or growth (Lazarus & Folkman, 1984).

Secondary appraisal is the process of recognizing the available coping resources or options. The judgment of secondary appraisal is concerned with what might and can be done. Primary and secondary appraisals often occur simultaneously and interact with each other in determining psychological stress (Lazarus & Folkman, 1984).

Reappraisal refers to a changed appraisal based on new information from the environment. A reappraisal differs from an appraisal only in that it follows an earlier appraisal in the same encounter and modifies it. Sometimes reappraisals are the result of cognitive coping efforts (Lazarus & Folkman, 1984).

Although psychological stress theory centers on individuals' appraisals of events, there has been little development of perceived stress measures (MacArthur & MacArthur, 2000). The Stress Appraisal Measure (SAM) provides the basis for assessing appraisal of a specific stressor. This instrument was based on Lazarus and Folkman's cognitive-appraisal theory. The SAM includes six dimensions of primary and secondary appraisals consisting of threat, challenge, centrality, controllable-by-self, controllable-by-others, and uncontrollable-by-anyone. Items were generated for each dimension as well as for overall perceived stress (Peacock & Wong, 1990). However, the SAM requires further psychometric evaluation data for measurement of different subject populations (Cohen et al., 1995; MacArthur & MacArthur, 2000).

In contrast to the SAM, the Perceived Stress Scale (PSS) based on Lazarus and Folkman's stress appraisal theory has been used widely to assess the appraisal of the amount of mental and physical stress in one's life rather than focusing on responses to specific stressors (Cohen, Kamrack, & Mermelstein, 1983). This instrument measures the degree to which situations in one's life are appraised as stressful. It was designed to tap how unpredictable, uncontrollable, and unmanageable respondents find their lives. However, the predictive validity of the PSS has been shown to fall off rapidly after 4 to 8 weeks because levels of stress appraisal are influenced by daily hassles, major events, and changes in coping resources.

There are three versions of the PSS, including 4 items, 10 items, and 14 items. The 10-item version of PSS (PSS-10) was used in the current study because the study sought to measure the degree to which situations in one's life are appraised as stressful. The PSS-10 also proved to be a good predictor of health and health-related outcomes and had maximum internal reliability in adults in the United States of America (Cohen et al., 1983; Cohen & Williamson, 1988). In addition, the questions are easy to understand and do not tie appraisal to particular events. Lastly, the response alternatives are simple to select.

The measurement of stress in this study was based on Lazarus and Folkman's (1984) cognitive appraisal theory. The study incorporated their view, in terms of individuals' appraisals of events as either threatening or challenging, and emphasized subjective evaluations of individuals' abilities to cope with demands or stressors. The study also recognized that perceived stress, which is an important mediator linking stressful situations and responses, is likely different among individuals faced with similar situations. These differences may be explained either by different appraisals or by differently coping styles.

In summary, the study of stress has been influenced by three different conceptions of stress: stress as a response, stress as a stimulus, and stress as a transaction. This study focused on psychological stress based on Lazarus and Folkman’s stress appraisal theory. This theory focused on person-environment transactions and identified three kinds of cognitive appraisal, which included primary appraisal, secondary appraisal, and reappraisal. These three appraisals emphasized the role of cognitive appraisal in assessing stressful situations and selecting coping options. The PSS-10, based on stress appraisal theory, was used to measure perceived stress among meditators in the study.

Blood Pressure and Its Physiology

Blood pressure is the force employed by the blood against the walls of blood vessels and must be adequate to maintain tissue perfusion of the body during activity and rest. Blood pressure is determined primarily by cardiac output (CO) and systemic vascular resistance (SVR). Any factor increasing either or both CO or SVR increases BP. There are three major systems involved in the regulation of BP, the ANS, the renal system, and the endocrine system, as shown in Figure 1 (Hamilton & Ignatavicius, 2002; Perrin, 2002). The ANS, including both the SNS and the PNS, is the short-term system regulating BP within a few seconds. Changes in the balance of SNS and PNS activity occur in response to messages sent by baroreceptors and stretch receptors. When the arterial walls are

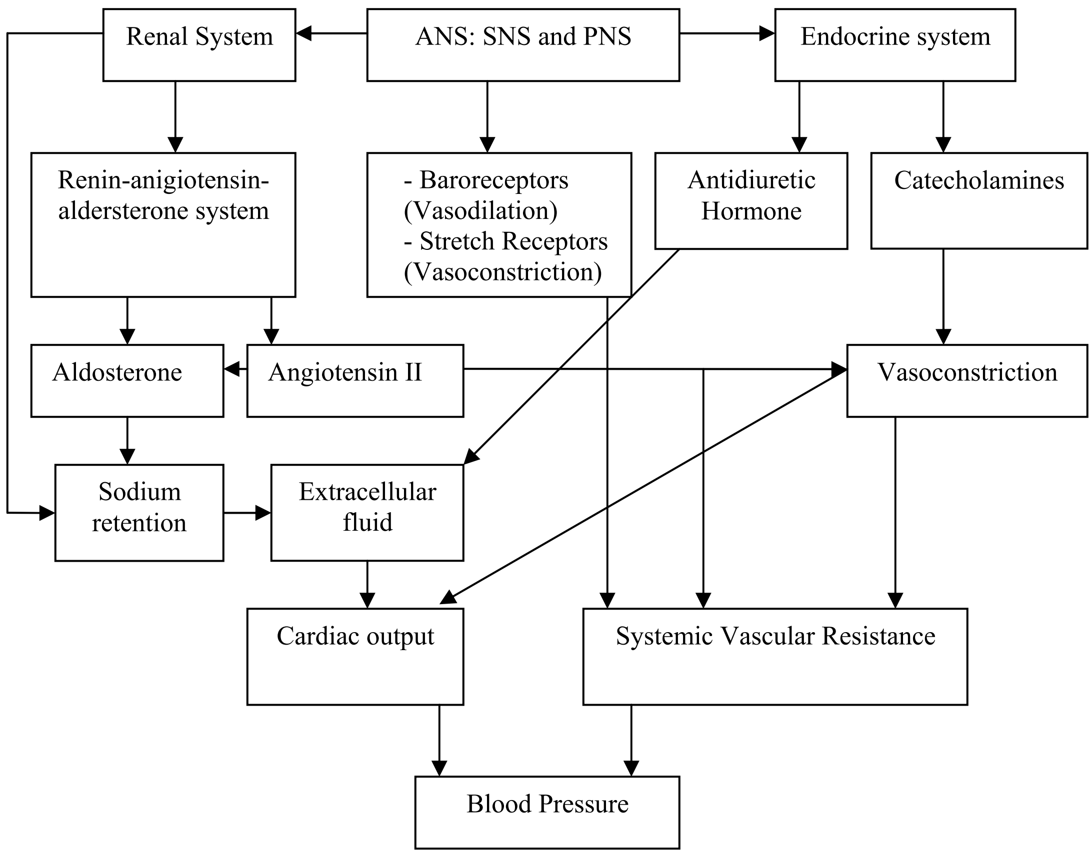

Figure 1. Physiology of blood pressure

Adapted From "Interventions for Clients with Vascular Problems," by D.J. Hamilton and D.D. Ignatavicius, 2002, *Medical Surgical Nursing: Critical Thinking for Collaborative Care*, p. 734; and From "Nursing Management: Hypertension," by B.S.Levine, 2000, *Medical Surgical Nursing: Assessment and Management of Clinical Problems*, p. 818-9.

stretched by an increased BP, baroreceptors located in the arch of the aorta and the origin of the internal carotid arteries are stimulated, thereby inhibiting the vasomotor center, leading to decreased BP. On the other hand, when a person is hypovolemic leading to decreased BP, the stretch receptors located in the vena cava and the right atrium send impulses to the central nervous system (CNS), which stimulates the SNS to increase HR and constrict the peripheral blood vessels. Consequently, BP increases (Hamilton & Ignatavicius, 2002; Levine, 2000; Perrin, 2002).

The renal system regulates sodium excretion and extracellular fluid volume. Sodium retention results in water retention, which causes an increased extracellular fluid volume. Consequently, the stroke volume of the heart increases, resulting in elevated BP through an increased CO. In addition, the renin-angiotensin-aldosterone system is important to BP regulation. Sympathetic stimulation, decreased blood flow or decreased serum sodium concentration result in a release of renin, an enzyme secreted from the kidneys, which converts angiotensinogen to angiotensin I. Angiotensin I is converted to angiotensin II, which can increase BP by increasing vascular resistance by vasoconstriction. Angiotensin II also stimulates the adrenal cortex to release aldosterone, which causes sodium and water retention in the kidneys, resulting in increased blood volume and CO. As a result, BP increases (Hamilton & Ignatavicius, 2002; Levine, 2000; Perrin, 2002).

Stimulation of the SNS also results in release of the catecholamines, epinephrine and norepinephrine, which cause increased contraction of smooth muscle and vasoconstriction, resulting in increased peripheral resistance or CO, thereby elevating the

BP. Furthermore, an increased blood sodium osmolarity level stimulates a release of antidiuretic hormone (ADH) from the posterior pituitary gland. The ADH promotes water reabsorption in the distal and collecting tubules of the kidneys resulting in increased extracellular fluid, thereby elevating BP (Hamilton & Ignatavicius, 2002; Levine, 2000; Perrin, 2002).

In summary, three major systems regulate BP: the ANS, the endocrine system, and the renal system. These systems affect vasoconstriction, peripheral resistance, or sodium and water retention, leading to increased CO and SVR, thereby elevating BP.

Heart Rate Variability and Its Physiology

Heart rate variability is defined as the change in the time interval between heartbeats from beat to beat (MacArthur & MacArthur, 2000; Vrijkotte et al., 2000). It is a dynamic marker which appears to be responsive and sensitive to acute stress. It can be measured simply and non-invasively to investigate autonomic influence on the heart (Fei, Copie, Malik, & Camm, 1996; MacArthur & MacArthur, 2000; Schuit et al., 1999). Generally, SNS activity increases HR, while PNS activity decreases HR. Increasing HR results in decreased HRV. Reduced HRV has thus been used as a maker of decreased vagal activity. Therefore, HRV is a measure of the final result of rhythmic, integrated activity of the ANS (MacArthur & MacArthur, 2000; Matzner, 2003; Sato et al., 1998).

Heart rate variability is currently measured by using time domain methods and frequency domain methods. Generally, HRV is measured manually with time domain methods by using a continuous electrocardiograph (ECG) recording (Figure 2). In a continuous ECG recording, each QRS complex is detected, and the beat-to-beat (RR or

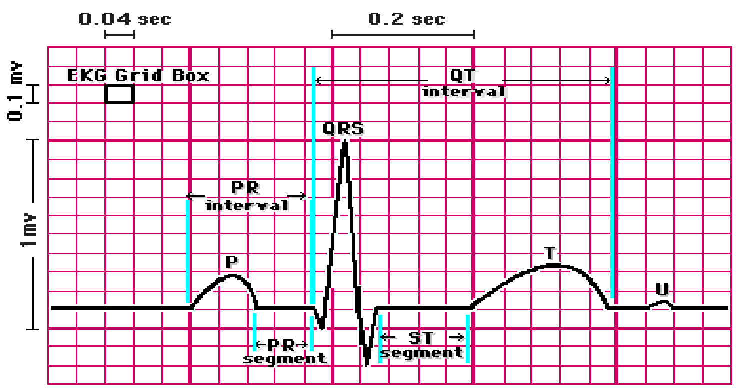

Figure 2. Normal electrocardiograph

From "http://cal.vet.upenn.edu/lgcardiac/ecg_tutorial/heartrate.htm."

NN) interval is determined. All RR intervals between contiguous QRS complexes, which result from sinus node depolarization, also known as the instantaneous HR, are detected. Time domain methods are based on an analysis of the mean RR interval and variations of the standard deviation of HR over time. The simplest calculation is the standard deviation of the RR or NN interval (SDNN), which reflects all cyclic components for variability during a recording period. The square root of the mean squared differences of successive NN intervals (RMSSD) is one of the most commonly used measures of short-term variation in order to estimate high frequency variations (MacArthur & MacArthur, 2000; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrotophysiology, 1996).

Frequency domain methods are analyzed by using power spectral analysis of short-term and long-term ECG recordings in order to quantify the signal's HRV frequency contents (Figure 3). These frequencies, total power of spectral analysis, consist of very low frequency (VLF: ≤ 0.04 Hz), low frequency (LF: 0.04-0.15 Hz), and high frequency (HF: 0.15-0.4 Hz) components of HRV. Total power and HF power are associated with SDNN and RMSSD, respectively. These correlations exist because of both mathematical and physiological relationships (MacArthur & MacArthur, 2000; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrotophysiology, 1996).

In humans, LF power and HF power are the two major spectral components. Low frequency power corresponds to BP variability and is jointly modulated by the SNS and the PNS. High frequency power is an accepted marker of vagal modulation of sinoatrial node activity and is associated with respiratory sinus arrhythmia attributed to PNS activity. In addition, the LF/HF ratio is a useful index of the balance of the SNS and PNS, with an increase in the ratio suggesting an increase in sympathetic cardiac modulation, a decrease in parasympathetic modulation or both (Cowan et al., 1990; Furlan et al., 2000; MacArthur & MacArthur, 2000; Sakakibara & Hayano, 1996; Sato et al., 1998; Stauss, 2003; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrotophysiology, 1996).

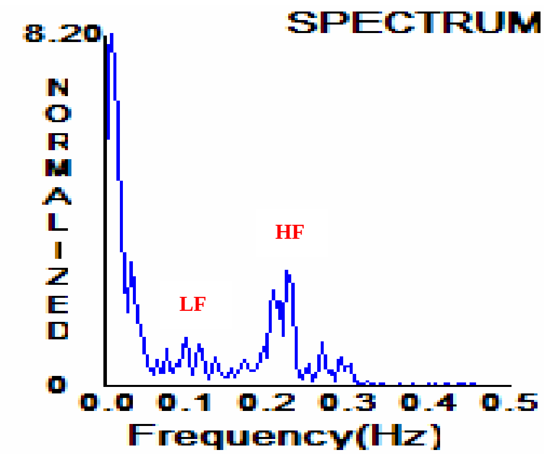

Figure 3. Participant's spectral components of HRV during meditation practice

Regarding the mechanisms for regulation of HRV, the ANS generates the autorhythmicity of the sinoatrial node at the posterior wall of the right atrium which adds variability to the HR signal at different frequencies. The sympathetic influence on HR is mediated by release of epinephrine and norepinephrine, resulting in an accelerating rate of the slow diastolic depolarization and HR, thereby increasing the LF power of HRV.

On the other hand, the parasympathetic influence on HR is mediated by release of acetylcholine, decreasing the rate of the slow diastolic depolarization and HR, thereby increasing the HF power of HRV. In addition, it is posited that the PNS influences the sympathetic effects probably by two mechanisms: cholinergic reduction of norepinephrine released in response to sympathetic activity and cholinergic attenuation of the response to an adrenergic stimulus, leading to an increase in the HF power and a decrease in the LF power (Stauss, 2003; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrotophysiology, 1996).

Measurement of both LF power and HF power in normalized units (n.u.) was used in this study to investigate autonomic influences of meditation on the heart. Normalization is obtained by dividing the absolute power of each component by the total power within a range of 0.04 and 0.5 Hz and multiplying by 100. Normal values of spectral analysis of stationary supine 5-min recordings are provided in Table 1 (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrotophysiology, 1996).

In summary, HRV is a simple non-invasive measure for investigating autonomic influence on the heart. Thus, HRV is an important variable in developing an understanding of the effects of meditation on the ANS.

Table 1

Normal Value of Spectral Analysis of Stationary Supine 5-min Recordings

Variables	($M \pm SD$)
LF power (n.u.)	54 ± 4
HF power (n.u.)	29 ± 3
LF/HF	1.5−2.0

Note. LF = Low frequency, HF = High frequency, and n.u. = Normalized unit.

Blood Pressure and Heart Rate Variability in Response to Exposure to Stressors

When an individual is exposed to an acute psychological stressor, the body prepares either a fight or flight response generated by the SNS and the PNS. Cardiovascular reactivity, including BP and HRV, is affected through SNS and PNS activity, which influences endocrine hormones as shown in Figure 4. The SNS causes the medulla of the adrenal gland to release the catecholamines, including epinephrine, norepinephrine and dopamine, resulting in increased contraction of smooth muscle and vasoconstriction, thereby increasing BP and decreasing HRV (Benson, 1975; Freeman & Lawlis, 2001; Furlan et al., 2000; Hjortskov et al., 2004; MacArthur & MacArthur, 2000; Stauss, 2003; Witek-Janusek & Werner, 2000).

Simultaneously, hypothalamic stimulation generates secretion of corticotropin releasing factor (CRF), causing the anterior pituitary gland to release adrenocorticotropic hormone (ACTH). ACTH stimulates the cortex of the adrenal gland to release glucocorticoids (primarily cortisol) and mineralocorticoids (primarily aldosterone) (Benson, 1975; Freeman & Lawlis, 2001; Witek-Janusek & Werner, 2000). Cortisol is important for the stress response. This hormone induces a number of physiological effects, which include potentiation of the action of catecholamines, increased blood glucose levels, and inhibition of the inflammatory response. Cortisol acts not only to support the adaptive response of the body to stressors, but also to suppress potentially self-destructive responses such as stabilizing the membranes of cellular lysosomes and preventing increased permeability, thereby decreasing inflammatory response. Aldosterone acts by retaining

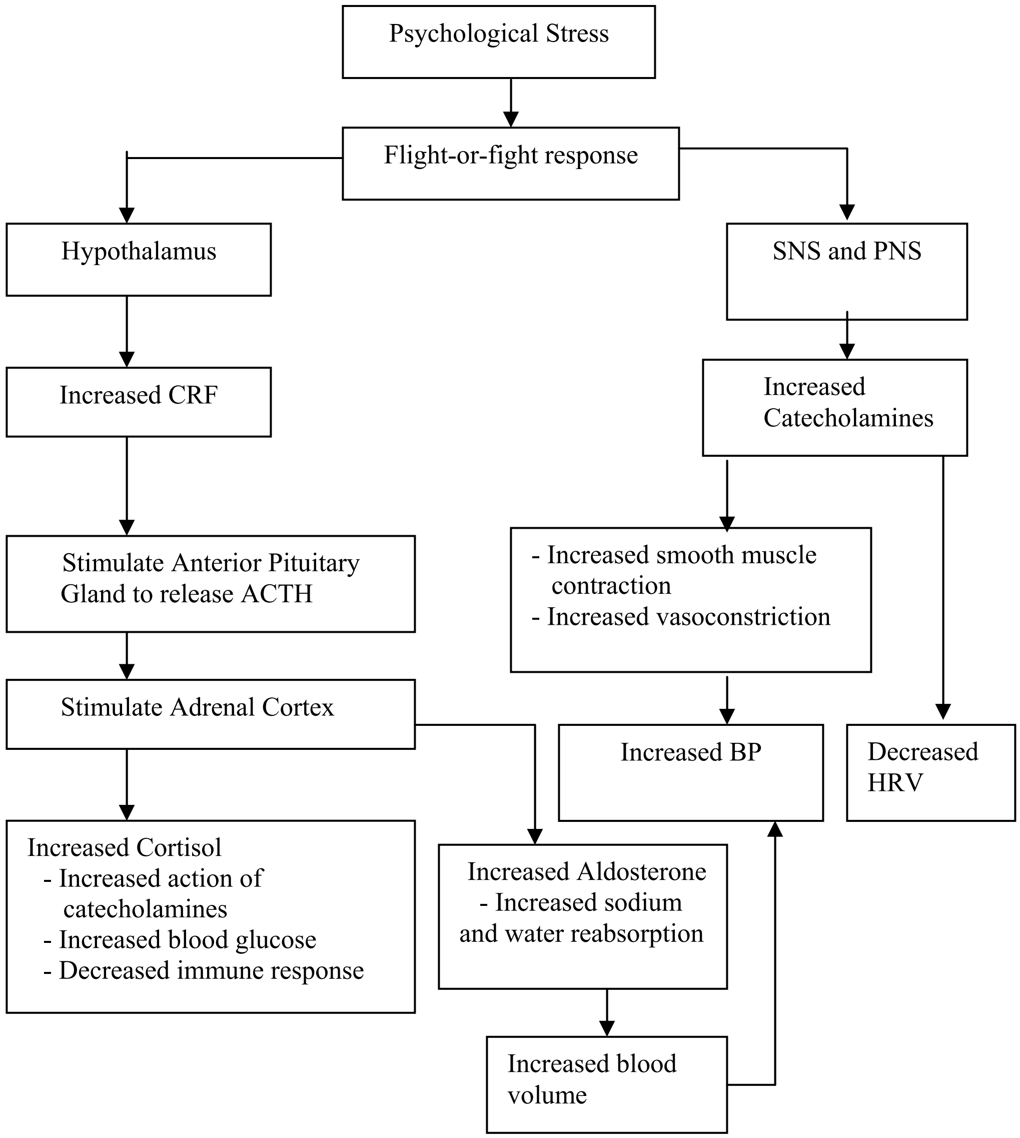

Figure 4. Blood pressure and heart rate variability in response to exposure to stressors

Adapted from "Nursing Management: Stress," by L. Witek-Janusek and J.S. Werner, 2000, *Medical Surgical Nursing: Assessment and Management of Clinical Problems*, p. 96-97.

extra sodium, resulting in increased water retention. As a result, BP increases (Benson, 1975; Freeman & Lawlis, 2001; Hjortskov et al., 2004; Witek-Janusek & Werner, 2000).

Exposure to chronic psychological stress may have direct negative effects on the cardiovascular system by exhausting biological resources for adapting to stressors. Chronic psychological stress leads to sustained SNS activity resulting in increased catecholamine secretion, thereby increasing BP and decreasing HRV. This results in damaging the ability of the vessels to dilate in response to an increased pressure load (Hjortskov et al., 2004; Matthews et al., 2002; Troxel, Matthews, Bromberger, & Sutton-Tyrrell, 2003).

In summary, when an individual appraises an environment or stressor as exceeding his or her resources and endangering his or her well-being, the body prepares either a fight or flight response generated by the SNS and the PNS, affecting the release of catecholamines, cortisol, and aldosterone. Consequently, BP increases and HRV decreases.

Meditation and Its Mechanisms of Action

The word meditate comes from the Latin *meditari*, which means to think or reflect upon (Bonadonna, 2003). Meditation can be defined as the intentional self-regulation, self-management and self-mastery of attention from moment to moment (Delmonte, 1985; Goleman & Schwartz, 1976). This approach also refers to a relaxation response, a unique state of consciousness, or both because in many forms of meditation, meditators are required to relax and combine both concentration and mindfulness (Murata et al., 2004). Shapiro (1982) defined meditation as “a family of techniques, which have in common a conscious attempt to focus attention in a non-analytical way and an attempt not to dwell on discursive ruminating thought” (p.268). Meditation generally trains attention, facilitates transcendence, ends suffering, and transforms human consciousness (Bonadonna, 2003). Therefore, the focus in meditation involves training the mind to become attuned to specific processes or contents of consciousness.

Meditation is also used as a broad and generic term, referring to a general category of spiritual practices. The objective of meditation in this sense is to enhance spiritual development through a process of deepening the range of the human spirit and changing the entire life of a human being (Cornelissen, 2001). Thus, the practice of meditation can lead an individual to be connected with other people and the higher energy of the universe. If one regularly practices meditation, one may develop an enhanced spiritual understanding that produces positive effects on physical and psychological functioning. As a result, healing emerges in one's life. The person will feel whole, in harmony and balanced (Watson, 1997). Consequently, meditators may ultimately reach a mystical state of "oneness" or "unity."

Though meditation has been practiced around the world for thousands of years, the total number of meditators is unknown. In Western societies, meditation has become more widely popular in the last four decades as an adjunct to conventional medical therapies. It is estimated that more than two million Americans have learned transcendental meditation, while mindfulness meditation is taught as a basis for more than 100 stress reduction programs (Bonadonna, 2003).

Several small studies have reported that meditation use ranged from 10% to 32% among study participants. Gulla and Singer (2000) conducted a cross-sectional survey to assess emergency department patients' use of alternative therapies in New York. Of the

139 patients, 19% used meditation as one form of alternative therapy. In other study, the use of meditation in 174 urban emergent patients of a Catholic tertiary teaching center was only 10.3% (Rolniak, Browning, MacLeod, & Cockley, 2004). Regarding meditation use in older adults, Cuellar, Aycock, Cahill, and Ford (2003) found that in 183 elders using 10 community service organization, approximately 30% of African Americans (12 out of 40) and 22% Caucasians (32 out of 143) used meditation. In another sample of 60 older adults in three ethnically diverse populations, researchers found that 32 % used meditation, primarily to stay healthy (King & Pettigrew, 2004).

There are many different forms of meditation that have been developed and passed on by religious and spiritual traditions. Many involve some form of withdrawal of attention from the outer world and from customary patterns of perceptual, cognitive, emotional, and motor activity (Bogart, 1991). These meditation techniques also share many of the same subjective outcomes, such as detachment, equanimity, and clearer sensory perceptions (Bonadonna, 2003). Shapiro (1982) stated that the practice of these different techniques utilized different attention styles. Thus, meditation has been divided into two major attention techniques, concentration meditation and mindfulness meditation (Delmonte, 1985; Goleman, 1976). However, Shapiro (1982) stated that when meditating, one can shift back and forth between the two techniques.

Concentration meditation aims at one-pointed attention to a single percept (Goleman, 1976). Thus, this technique attempts to exclude all other thoughts from awareness and focuses the attention on a single object such as a sound (mantra), a candle flame, and one’s breath (Delmonte, 1985; Shapiro, 1982). This method is similar to a zoom-lens attention on a very specific object (Delmonte, 1985; Shapiro, 1982). This approach induces states of absorption characterized by tranquility and bliss. Concentration meditation has been popularized in the form of transcendental meditation (TM), which is widely practiced in North America and Western Europe (Bogart, 1991; Delmonte, 1985). Transcendental meditation is the systematic and continued focusing of the attention on a single object or persistently holding a specific attentional set towards all percepts or mental contents as they spontaneously arise in the field of awareness (Goleman & Schwartz, 1976). This technique had its origin in the ancient Vedic tradition in India (Barnes et al., 2001).

Mindfulness meditation is defined as the state of being attentive to and aware of what is taking place in the present (Chang et al., 2004; Shapiro et al., 1998). Mindfulness meditation has its roots in the Theravada Buddhism tradition. Though this method includes concentrated awareness, it differs from concentration meditation which restricts attention to one single object. Mindfulness meditation teaches detached observing or witnessing of perceptions, cognitions, sensations, and awareness that arise during meditation (Astin, 1997; Goleman, 1976). Thus, mindfulness meditation is a formal discipline attempting to create greater awareness and insight in meditators as wide-angle-lens attention, attempting awareness of the whole perceptual field (Delmonte, 1985; Shapiro, 1982). Common versions of this meditation approach are vipassana and zen meditation (Delmonte, 1985). Vipassana involves training in mindfulness in which attention is focused upon registering feelings, thoughts, and sensations without elaboration, preference, selection, comments, censorship, judgment, or interpretation. It is focus on moment to moment awareness and a process of expanding attention to as many mental and physical events as possible. The goals of this method are to develop insight into the nature of psychic functioning and to increase understanding of the impermanent, unsatisfactory, and non-substantial nature of all phenomena (Bogart, 1991; Delmonte, 1985; Goleman, 1976; Shapiro et al., 1998). Similarly, zen meditation combines both concentration and mindfulness approaches. The goal of this approach is the "mindful state," which is awareness of objects, mind-states, and physical states, but not attachment to them (Delmonte, 1985). Thus, both vipassana and zen meditation involve training in mindfulness to perceive full awareness of all contents.

Meditation has been thought to elicit a relaxation response (Benson, 1975), which is believed to be an innate physiological response and the counterpart of the fight-or-flight response (Lehmann & Benson, 1982). The relaxation response is thought to have beneficial effects by inducing a positive parasympathetic state, and counteracting the increased SNS activity that accompanies the fight-or-flight response. Goleman and Schwartz (1976) suggested that meditation proved to be an effective means for stimulating resistance to stressor, and inhibiting a generalized low arousal pattern of responses characterized by sympathetic activity, which might prove to inhibit the autonomic activity seen in the stress response. As a result, oxygen consumption, respiration rate, HR, BP, arterial blood lactate, and skin conduction response decrease (Benson, 1975; Benson, 1993; Bogart, 1991; Goleman & Schwartz, 1976; Lehmann & Benson, 1982). Relaxation also leads to reduced psychological stress (Astin, 1997; Benson, 1975; Chang et al., 2004; Goleman & Schawartz, 1976; Shapiro et al., 1998; Waelde et al., 2004) and increased HRV (Matzner, 2003; Murata et al., 2004; Peng et al., 1999; Peng et al., 2004; Takahashi et al., 2005). Different effects of meditation may be also associated with different levels of meditation practice. Thus, long-term meditators may experience different physiological, cognitive, and psychological changes and states as compared to novice meditators (Bogart, 1991).

In summary, meditation, which can be used as a psychological healing intervention, is the accomplishment of a deeply relaxed but fully alert state practiced as a self-regulatory modality for stress reduction and emotional management. Meditation is thought to elicit the relaxation response. The relaxation response may decrease SNS activity and increase PNS activity, thereby reducing the stress response, decreasing BP, and affecting HRV by decreasing LF power and increasing HF power.

Significance

The relaxation and stress reduction that are claimed to result from meditation may have prophylactic and therapeutic health benefits. Meditation is thought to decrease psychological stress, augment PNS activity and reduce SNS activity, leading to decreased BP, decreased LF power, and increased HF power in many studies (Astin, 1997; Barnes, Treiber, & Davis, 2001; Barnes, Treiber, & Johnson, 2004; Barnes, Treiber, Turner, Davis, & Strong, 1999; Chang et al., 2004; Goleman & Schawartz, 1976; Murata et al.,2004; Pelletier, 1993; Peng et al., 1999; Peng et al., 2004; Shapiro et al., 1998; Sudsuang, Chentanez, & Veluvan, 1991; Takahashi et al.,2005; Waelde et al., 2004; Wallace, Silver, Mills, Dillbeck, & Wagoner, 1983). However, no known studies have simultaneously examined relationships among perceived stress, BP, HRV, and meditation practice. Thus, the relationships among perceived stress, BP, HRV and meditation practice in meditators have not been clearly defined. This information would provide a clearer understanding of the physiological and psychological benefits of meditation.

Research Model

This study was conducted to examine the relationships among perceived stress, BP, HRV, and meditation practice in meditators. An assumption was made that among meditators, there is variability in quantity of meditation practice, type of meditation practice, and stress levels. Thus, these variables can effectively be examined with respect to the effects of meditation on stress and physiologic indicators. Figure 5 illustrates the model showing that perceived stress generates increased SNS activity and decreased PNS activity, resulting in increased BP and LF power, and decreased HF power of HRV. However, meditation is hypothesized to reduce perceived stress, which would result in decreased SNS activity and increased PNS activity, and be observable as decreased BP and LF power of HRV, and increased HF power of HRV. This model was tested, via two research hypotheses, in this study.

Summary

In this chapter, the purpose of the study was described and the background and significance of the study were presented. An overview of psychological stress, BP, HRV, and meditation practice was provided from a theoretical perspective. The chapter also included the research hypotheses and a research model specifying relationships among study variables. The next chapter will summarize the state of the science with respect to the variables of interest in this study.

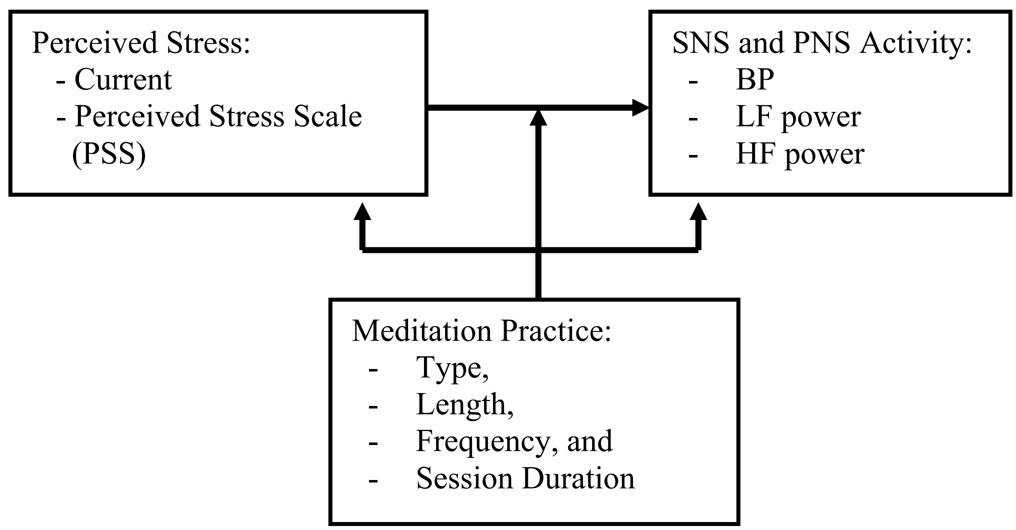

*Figure 5***.** Research model of relationships among perceived stress, blood pressure, heart rate variability and meditation practice.

Chapter 2

Literature Review

The purpose of this chapter is to present the conclusions from the review of relevant published research literature. This review provides current information about the state of knowledge with respect to the variables of concern and their relationships to each other. A total of 140 articles were identified via electronic search using Medline and the following search terms: stress, blood pressure (BP), heart rate variability (HRV), and meditation or relaxation techniques. Reference lists from relevant articles were also reviewed to identify other articles. Articles were included in this review if the publication was a report of research, written in English, included at least two variables of interest, and focused on healthy persons without cardiovascular disease. Additionally, research reporting HRV was included only if HRV was measured using the frequency domain method. A total of 30 articles met these criteria.

There were six major conclusions from the review of the 30 articles. There were: a) inconsistent findings of the effects of psychological stress on HRV; b) there were inconsistent findings with respect to the effects of psychological stress on BP; c) there were inconsistent findings on the effects of meditation on psychological stress; d) there were inconsistent outcomes regarding the effects of meditation on HRV; e) there were inconsistent findings with respect to the effects of meditation on BP; and f) there were no studies located which simultaneously examined relationships among psychological stress, BP, HRV and meditation practice. Each of these conclusions and supporting studies will be described in more detail in the following sections.

Effects of Psychological Stress on Heart Rate Variability

Five studies documented the effects of psychological stress on HRV (Furlan et al., 2000; Hjortskov et al., 2004; Kang et al., 2004; Papousek et al., 2002; Sloan et al., 1996). Two studies were conducted in male industrial workers (Furlan et al., 2000; Kang et al., 2004), while another study used mostly male healthy volunteers (Sloan et al., 1996). The others employed students (Hjortskov et al., 2004; Papousek et al., 2002). Three studies used a mental stress task (Hjortskov et al., 2004; Papousek et al., 2002; Sloan et al., 1996) and the others employed job stress (Furlan et al., 2000; Kang et al., 2004) as a psychological stressor. Two studies revealed significant decrease in low frequency (LF) power (Furlan et al., 2000; Sloan et al., 1996), while another study showed insignificant decrease in LF power (Kang et al., 2004). Other researchers reported either unchanged LF power (Papousek et al., 2002) or insignificant increase in LF power (Hjortskov et al., 2004). Most study findings demonstrated a significantly decreased high frequency (HF) power in response to either a mental stress task or job stress (Hjortskov et al., 2004; Papousek et al., 2002; Sloan et al., 1996), while Furlan et al. (2000) reported a significant increase in HF power. In terms of LF/HF ratio, findings have been similarly inconsistent. Reports included those in which LF /HF ratios were increased (Hjortskov et al., 2004), decreased (Furlan et al., 2000) and either statistically insignificant or unchanged (Kang et al., 2004; Sloan et al., 1996). The summarized findings of studies that reported HRV data are shown in Table 2. Each study related to this conclusion will be also described in narrative detail in the following sections.

Furlan et al. (2000) conducted a cross-sectional study to examine the effect of changes in work time over 24 hours on HRV. Twenty-two healthy male blue-collar workers participated in the study. Participants had 24-hour electrocardiograph (ECG) recorded during three different work shifts (first shift from 6 am to 2 pm, second shift from 2 pm to 10 pm, and third shift from 10 pm to 6 am) and were asked to maintain a daily routine as usual. The series of consecutive RR intervals from ECG recordings were calculated by using computer program as a function of beat number. Two major components of HRV were extracted from RR variability: HF power (≈ 0.25 Hz), an accepted marker of vagal modulation of the sinoatrial node activity; and LF power (≈ 0.10 Hz), a marker of cardiac sympathetic modulation. The findings showed that LF power and LF/HF during work periods were significantly higher compared to sleep periods within the same work shift, while the HF power was significantly lower during the same periods of time. Comparing working periods, people working the third shift (10 pm to 6 am) had significantly higher HF power and significantly lower LF power and LF/HF ratio compared to those working the first and second shifts. The researchers speculated that decreased values of cardiac sympathetic modulation during night shift might be related to sleepiness or diminished alertness leading to accidents and errors. They also suggested that continuous changes of cardiac sympathetic modulation might be associated with increased cardiovascular diseases (Furlan et al., 2000).

Table 2

Effect of Psychological Stress on Heart Rate Variability

Authors	Research design/ Sample	Statistical findings		
		LF power	HF power	LF/HF ratio
Furlan et al.(2000)	Cross-sectional study/ 22 healthy male workers	Decreased	Increased	Decreased
Kang et al. (2004)	Cross-sectional study/ 169 male workers	Decreased (*ns*)	Decreased (*ns*)	Increased (*ns*)
Hjortskov et al.(2004)	Quasi-experimental design/ 12 female students	Increased (*ns*)	Decreased	Increased
Papousek et al.(2002)	Quasi-experimental design/ 111 university students	Unchanged	Decreased	Not reported
Sloan et al. (1996)	Quasi-experimental design/ 34 healthy volunteers	Decreased	Decreased	Unchanged

Note. LF = Low frequency. HF = High frequency. *ns* = Nonsignificant.

With contrasting results, using a cross-sectional study, Kang et al. (2004) used a cross-sectional design to examine the relationship between job stress and HRV. A total of 169 male industrial workers were included in the study. Participants were divided into two groups according to postulates of the strain model including 121 in the low strain group and 46 in the high strain group. All participants completed the Job Content Questionnaire (JCQ), which had two dimensions of job characteristics, work demand and decision latitude. A high score represented a high level of perceived job stress. The HRV, which was a measurement of the interaction in the autonomic nervous system (ANS) and reflected all physiological factors adjusting normal rhythm of the heart, was measured by the SA-2000E model (manufactured by Medi-core 2002). Electrodes were placed on participants' wrists and left foot for five minutes. The results showed that LF power and HF power in a high strain group were lower than a low strain group, but were not significantly different. The LF/HF ratio rose in the high strain group compared to the low strain group, but again, the increase was not statistically significant. The lack of significant findings might result from lack of the power analysis to ensure that the sample size was large enough to detect the expected difference between groups. In addition, it is possible that the participants might not have any job stress arousal during HRV recording. The researchers concluded that sympathetic arousal and decreased HRV in high strain group may be useful surrogate indicators for potential cardiovascular dysfunctions.

Hjortskov et al. (2004) used a quasi-experimental design with non-probability sampling to assess the cardiovascular reactivity and subjective stress response to a combination of cognitive and emotional stressors during standardized computer work sessions in twelve female students without earlier experience of laboratory experiments. The participants performed three ordering sessions of computer tasks: introductory, stress, and control sessions. The ECG was recorded continuously during the experiment in order to obtain HRV. The participants also reported their subjective experiences of stress (SES), consisting of six different stress scales: stressed, tensed, exhausted, concentrated, stimulated, and happy. Data were collected at four time points: before the beginning of computer task and once at the end of each of the three work sessions. The results revealed significantly reduced HF power and increased LF/HF ratio during the stress session compared to the control session. There was no difference in LF power, when comparing the stress session and control session. Both LF power and HF power were significantly higher during three rest periods compared to the three work sessions; however, LF/HF ratio was significantly decreased during rest periods compared to work sessions. Researchers concluded that stressors led to changes in HRV. Resting had a positive effect on HRV (Hjortskov et al., 2004). However, the study was conducted in a laboratory and findings may not be reproducible in an occupational setting. The small sample size should be considered for the generalizability of the study findings.

Reporting similar results, Papousek et al. (2002) used a quasi-experimental design to examine ANS reactivity to an emotional stress in 111 university students who volunteered to participate. The ECG was recorded using a standard limb lead II electrode configuration in order to obtain HRV at rest and during emotional stress using public speaking. The findings showed a significantly greater decrease in HF power from the rest to stress condition, but contrary to hypothesized outcomes, LF power did not change. It is possible that the stressful situation (public speaking) may not have been sufficiently stressful to elicit a cardiac sympathetic response.

In another study, Sloan et al. (1996) used a quasi-experimental design to demonstrate the relationship between LF power and mental stress. Thirty-four healthy volunteers, 31 men and 3 women, were participants. All participants had ECG measured using Holter recordings during a 5-minute baseline and a 5-minute mental arithmetic task. The mental arithmetic task consisted of subtraction by 7’s beginning with 2193 on a computer numeric keypad. The results revealed that LF power and HF power significantly decreased from baseline to the stressor condition. Unexpectedly, the LF/HF ratio, which represented sympathovagal balance, was unchanged. A power analysis was not reported, thus the sample size could have been too small to detect any differences that actually existed. In addition, the study was conducted in a laboratory so the generalizability of the study findings to usual living conditions might be limited.

In summary, there were five studies focused on the effects of psychological stress on HRV using both quasi-experimental and descriptive designs, and including various types of subjects. Most findings documented that the effects of psychological stress on HRV included a decreased HF power and LF power. Two studies showed increased LF/HF ratio. The major limitation evident across several studies was that there may have been an insufficient amount of psychological stress, thus failing to provoke sympathetic arousal.

Effects of Psychological Stress on Blood Pressure

There were 10 published studies that addressed the effects of psychological stress on BP (Carroll, Christopher, Hunt, Ford, & Macintyre, 2003; Carroll et al., 2001; Fauvel, 2003; Hjortskov et al., 2004; Kang et al., 2004; Lindquist, Bellin, & Knuiman, 1997; Matthews, Gump, & Owens, 2001; Sloan et al., 1996; Vrijkotte et al., 2000; Weinrich et al., 2000). Studies were conducted in variety of populations such as adolescents, adults, males, or white-collar workers. There were three kinds of psychological stress studied: environmental stress, job stress and mental stress task. The findings showed that there were inconsistent effects of psychological stress on BP, though most studies documented that psychological stress was associated with significantly higher systolic and diastolic BP (Carroll et al., 2001; Carroll et al., 2003; Hjortskov et al, 2004; Matthews et al., 2001; Sloan et al., 1996; Weinrich et al., 2000). One study showed increased systolic BP only

(Vrijkotte et al., 2000) and three studies revealed no effect on either systolic BP or diastolic BP (Fauvel, 2003; Kang et al., 2004; Lindquist et al., 1997). The summarized findings are displayed in Table 3. Each study will be described in more detail in the following sections.

Lindquist et al. (1997) used a correlational design to clarify whether perceived work stress directly affected long-term BP. The convenience sample consisted of 337 men and 317 women who were healthy and worked in an Australian government tax office. Participants completed the Occupational Stress Indicator (OSI), which measured job-related stress and stress-related coping strategies. The split half reliability coefficients for job stress were 0.89 for men and 0.91 for women; and for home/work stress were 0.81 and 0.83 for men and women, respectively. Participants had seven resting BP measurements measured serially on each of two occasions a week apart using a Dinamap 1846SX/P oscillometric recorder. The results showed that men had significantly higher systolic and diastolic BP than women. Using Pearson correlation coefficients and multiple regression analysis, researchers demonstrated no direct correlations between work stress and BP. Researchers concluded that work stress had indirect effect on systolic and diastolic BP. The researchers suggested that a program designed to prevent high BP in the workplace should focus not only on the working environment but also on the way individuals perceive stress (Lindquist et al., 1997). The reliability of the BP measurement is questionable, given that there was no documentation of instrument standardization procedures.

Table 3

Effect of Psychological Stress on Blood Pressure

Authors	Research design/ Sample	Statistical findings	
		Systolic BP	Diastolic BP
Lindquist et al. (1997)	Correlational design/ 654 healthy volunteers	Unchanged	Unchanged
Fauvel et al. (2003)	Cohort study/ 292 healthy volunteers	Unchanged	Unchanged
Carroll et al. (2001)	Cohort study/ 796 middle-aged male	Increased	Increased
Carroll et al. (2003)	Cohort study/ 990 healthy participants	Increased	Increased
Kang et al. (2004)	Cross-sectional design/ 169 male workers	Increased (*ns*)	Increased (*ns*)
Vrijkotte et al. (2000)	Cross-sectional design/ 109 male workers	Increased	unchanged
Weinrich et al. (2000)	Cross-sectional design/ 1079 students	Increased	Increased
Hjortskov et al. (2004)	Quasi-experimental study/ 12 female students	Increased	Increased
Matthews et al. (2001)	Quasi-experimental study/ 62 healthy volunteers	Increased	Increased
Sloan et al. (1996)	Quasi-experimental study/ 34 healthy volunteers	Increased	Increased

Note. BP = Blood Pressure. *ns* = Nonsignificant.

Reporting similar results, Fauvel et al. (2003) used a cohort study to examine the influences of stress perception and cardiovascular reactivity to a mental stress test on BP. Researchers viewed psychological stress as a major environmental factor in the genesis of hypertension. A total of 292 healthy volunteers employed in a chemical company were followed up at least one year and divided into high strain (n = 61) and non-high strain (n = 232) using the median cut points of a job strain questionnaire. Eighty four participants discontinued for 5-year follow-up because of retirement, job transfer, hypertension, and death. Participants with high reactivity (n = 61) representing the highest stress-induced systolic BP were compared to a non-high reactivity group (n = 226). All participants had BP recorded at a baseline, using a mercury sphygmomanometer, and at a 5-year follow-up during work and a rest period using an ambulatory BP monitor (Spacelabs 90207) for 24 hours, which was not reported the instrument standardization. Researchers reported that 154 ambulatory BP were valid according to standard criteria. The results revealed that neither the high strain nor high reactivity group had significant increases in systolic and diastolic BP over time, though the sample size was based on a power analysis and was sufficiently large to detect the expected difference between groups. However, the mortality threat should be considered. The instrument may have failed to measure job strain adequately, or BP readings may have been taken with different equipment or by different researchers or using different techniques for each of the two measures (Fauvel, et al., 2003).

As described earlier, Kang et al. (2004) used a cross-sectional study and measured BP in examining the effects of job stress in 169 male workers. Participants completed the

Job Content Questionnaire (JCQ) and had BP recorded using a standard mercury sphygmomanometer. Two measurements were taken and the results were averaged. The results showed that the high strain group had an increase in both systolic and diastolic BP compared to the low strain group, but the difference was not statistically significant. The lack of significant findings might have resulted from an insufficiently large sample size to detect the expected difference between groups, as a power analysis was not reported.

In contrasting study findings, Vrijkotte et al. (2000) used a cross-sectional design to examine the effect of work stress on BP. Participants included a volunteer sample of 109 male white-collar workers at a computer company. Work stress referred to an effort-reward imbalance. According to Siegrist's model (Vrijkotte et al., 2000), participants were divided into two work stress groups on the basis of their scores for imbalance and overcommitment using the effort-reward imbalance work stress questionnaire. Imbalance referred to a combination of high effort and low reward at work. Overcommitment was an exhaustive work-related coping style associated with the inability to withdraw from work obligations. While both patterns were conceptualized as being potentially stressful, the overcommitment group was viewed as being unable to disconnect from work and thus faced continuous exposure to work stress and was expected to have more adverse effects on BP and vagal tone. Each group was classified according to high imbalance, low imbalance, high overcommitment, or low overcommitment. All participants had BP recorded during waking hours using a Spacelabs 90207 device. The BP device was removed by participants during sleeping hours. All measurements were recorded during two workdays and one non-workday. The study revealed that being in the high imbalance group was significantly correlated with a greater systolic BP during work and leisure time, but diastolic BP was not different. Being in the overcommitment group was not correlated with systolic BP or diastolic BP. The findings suggested that work stress increased systolic BP (Vrijkotte et al., 2000). There was no report of instrument standardization. Thus, the reliability of the BP measurement is questionable.

Weinrich et al. (2000) used a cross-sectional design to measure the relationships between psychological distress and BP in adolescents exposed to Hurricane Hugo. A random sample of 1079 students from two urban high schools in South Carolina (School A and B) was used. Students in school A had major exposure to Hurricane Hugo one year before this study was conducted, and those attending School B did not. Participants' BP, obtained at a single reading, was measured using Labtron Model 03-175 aneroid sphygmomanometer by two nurse practitioners. Interrater reliability for BP readings among nurse practitioners was 0.94. Two to 4 weeks later, psychological distress was measured in term of anger, depression and anxiety by using two questionnaires: Spielberger Anger Expression Scale, which obtained good reliability between 0.73 and 0.85, and abbreviated versions of the depression and anxiety scales from the Derogatis's Brief Symptom Inventory (BSI), which had Cronbach alpha reliabilities of 0.78 for depression and 0.66 for anxiety. The results revealed that 5% of the 1079 students had elevated BP. Students in School A had significantly increased systolic and diastolic BP compared to students at School B. The researchers concluded that adolescents exposed to catastrophic events such as a hurricane should be considered as candidates for early intervention to prevent elevated BP (Weinrich et al., 2000). However, this study had limitations due to the use of a single BP reading and BP recording at a separate time from completion of the psychological questionnaires.

Reporting similar results, Carroll et al. (2001) used a cohort study to document whether BP reactions to mental stress predicted future BP. At ten years, follow-up screening BP data were available for 796 middle-aged male participants. All participants had BP recorded using a Hawksley random zero sphygmomanometer at an initial and follow-up medical screening. At each of those data collection points, two readings were taken and were averaged. The laboratory baseline BP and the BP during exposure to a mental stress task were measured using a Copal (UA 251) semiautomatic digital sphygmomanometer. Raven's matrices were served as the mental stress task, which provoked cardiovascular activity. The results revealed that the increases in systolic BP and diastolic BP to a mental stress task were significant compared to the initial and baseline BP. The strongest predictors of the follow-up BP were initial screening BP and baseline BP. The systolic BP reactions to mental stress were positively correlated with follow-up systolic and diastolic BP. There was no significant correlation between diastolic BP reactions to mental stress and follow-up systolic and diastolic BP. In multiple regression analysis, systolic BP reaction to mental stress was also a significant predictor of follow-up systolic BP. The researchers concluded that heightened BP reactions to mental stress contributed to elevate BP (Carroll et al., 2001). The study used two different instruments for recording BP, which casts some doubt on the validity of the conclusions related to changes in BP over time.

Two years later, Carroll et al. (2003) conducted a cohort study with the same purpose of the previous study. Five-year-follow-up data were available for 990 participants, 541 women and 446 men, from the Glasgow area. Participants were excluded if they took antihypertensive medicine or registered resting systolic BP 160 mmHg or more and diastolic BP 90 or more. All data were collected at participants' home. Resting BP was recorded by Omron (model 705 CP) semi-automatic sphygmomanometer at initial baseline, in response to a mental stress task using the paced auditory serial addition test (PASAT), and at five-year- follow-up. The results revealed similar findings to their previous study; increases in systolic BP and diastolic BP to a mental stress were statistically significant compared to initial baseline. The systolic BP reaction to stress was positively correlated with follow-up systolic BP. There was no correlation between diastolic BP reaction to mental stress and follow-up diastolic BP. However, in multivariate tests, systolic and diastolic BP reaction to mental stress could predict five-year increase in both systolic and diastolic BP. Researchers concluded that BP reactions to mental stress could predict future BP (Carroll et al., 2003). There was no documentation of instrument standardization. The reliability of equipment thus should be a concern.

Regarding intervention studies, Hjortskov et al. (2004), as described previously, also measured BP in evaluating the effect of a combination of cognitive and emotional stressors during standardized computer work sessions in 12 female volunteers. All participants had baseline BP recorded using an automatic BP device (Omron 705 CP). Beat-to-beat BP was continuously recorded during three work sessions, and during short and prolonged breaks using an automatic digital BP device (2300 Finapres BP Monitor, Ohmeda). The two instruments did not result in different BP measurement after correction for hydrostatic pressure was made. The participants reported their subjective experiences of stress four times: before the beginning of a computer task, and once at the end of each of the three work sessions. The results revealed that changes in systolic and diastolic BP were significantly higher during each of the three work sessions compared to baseline. The changes in systolic BP tended to be higher in the control session compared to the stress session and the changes in diastolic BP were significantly higher in the control session compared to the stress session. However, the study was conducted in a laboratory in order to control experimental conditions, thus generating a potential limitation related to applicability of findings.

Supporting the above findings, Matthews et al. (2001) reported similar results using a quasi-experimental design to investigate the influence of chronic stress on cardiovascular responses to and recovery from acute stressors. A total of 62 healthy, Caucasian, middle-aged volunteer participants were recruited to the study. All participants completed psychological questionnaires to measure chronic psychological stress: the Perceived Stress Scale-4 items version (PSS-4), the Job Environment Inventory, and the Dyadic Adjustment Scale. The PSS-4 was used to measure chronic stress that was not specific to job or relationship difficulties. The internal consistency of the PSS-4 in this study was 0.80. Participants also had BP measured using an IBS Model SD-700A automated BP monitor at baseline, during mental arithmetic and public-speaking tasks, and a relaxed period. The results showed that systolic and diastolic BP significantly increased during tasks. The systolic BP remained significantly increased in the recovery period. The researchers concluded that middle-aged healthy adults with high level of chronic stress displayed suppressed cardiovascular responses during acute stress and recovery periods. The reliability of the BP measurement is a concern due to no documentation of instrument standardization procedures.

As described formerly, Sloan et al. (1996) also measured BP in examining the effect of a mental stress task in 34 healthy volunteers. The mental arithmetic task consisted of subtraction by 7's beginning with 2193 on a computer numeric keypad. All participants had BP measured using an automated sphygmomanometer (Paramed) during the 5-minute baseline and 5-minute mental arithmetic task. The results revealed that systolic and diastolic BP significantly increased during the mental stress task. Researchers concluded that sympathetic arousal and withdrawal of parasympathetic modulation under stress increased in BP. The reliability of the BP measurement is questionable due to no report of instrument standardization procedures.

In summary, there were 10 articles that documented the effects of psychological stress on BP in a variety of subjects. The findings were inconsistent regarding the effects of psychological stress on BP. Six studies documented that psychological stress was associated with significantly higher systolic and diastolic BP. One study showed increased systolic BP only and three studies revealed no effect on either systolic BP or diastolic BP. The threat to internal validity in term of instrumentation effects was a concern in some studies. Some studies were conducted in a laboratory and had a small sample size; thus, limiting the application of the findings to non-laboratory settings.

Effect of Meditation on Psychological Stress

Six studies were reviewed which examined the effects of meditation on psychological stress (Astin, 1997; Chang et al., 2004; Goleman & Schawartz, 1976; Robinson, Mathews, & Witek-Janusek, 2003; Shapiro et al., 1998; Waelde et al., 2004). Each study was used different instruments to measure psychological stress. These instruments included the Perceive Stress Scale 10-item version (PSS-10) (Chang et al., 2004; Robinson et al., 2003), the Hopkins Symptom Checklist 90 (Revised; SCL-90-R) (Astin, 1997; Shapiro et al., 1998), the State and Trait Anxiety Inventory (Goleman & Schawartz, 1976; Shapiro et al., 1998; Waelde, et al., 2004), or the Center for epidemiological Studies Depression Scale (CES-D) (Waelde, et al., 2004). The results were inconsistent. Most study findings indicated that meditation could significantly reduce psychological stress (Astin, 1997; Chang et al., 2004; Goleman & Schawartz, 1976; Shapiro et al., 1998; Waelde, et al., 2004). Only one study revealed no effect of meditation on psychological stress (Robinson et al., 2003).The summarized findings are presented in Table 4. Each study will be described in more detail in the following sections.

Astin (1997) carried out an experimental study to examine the effects of an 8-week stress reduction program based on training in mindfulness meditation on psychological symptomatology. Twenty-eight volunteer undergraduate students were randomly assigned to either an experimental group or a control group. Twelve of the 14 participants in the experimental group and seven of the 14 participants in the control group completed post-intervention measures. Psychological symptomatology, resulting from excessive psychological stress, was measured using the Symptom Checklist-90 revised (SCL-90-R).

Table 4

Effect of Meditation on Psychological Stress

Author	Research design/ Sample	Instrument	Statistical findings
Astin (1997)	Experimental study/ 28 undergraduate students	SCL-90- R	Decreased
Shapiro et al. (1998)	Experimental study/ 78 premedical students	SCL-90, STAI-1	Decreased
Goleman & Schawartz (1976)	Quasi-experimental study/ 60 meditators and nonmeditators	STAI-1	Decreased
Chang, et al. (2004)	Quasi-experimental study/ 43 continuous students	PSS-10	Decreased
Waelde et al. (2004)	Quasi-experimental study/ 12 caregivers	CES-D, STAI	Decreased
Robinson et al. (2003)	Quasi-experimental study/ 24 patients with HIV infected	PSS-10	Unchanged *(ns)*

Note. SCL-90- R is the Symptom Checklist-90 revised; SCL-90 is the Hopkins Symptom Checklist 90; STAI-1 is the State and Trait Anxiety Inventory; PSS-10 is the perceived stress scale 10-item version; and CES-D is the Center for epidemiological Studies Depression Scale (CES-D). *ns* = Nonsignificant.

The control participants were told that they would be notified for the next available stress reduction program. The experimental group attended an 8-week stress reduction program using mindfulness meditation. This technique was viewed as both concentrative meditation and non-focal or opening-up meditation to reduce psychological stress. Experimental participants were asked to practice at home for 45 minutes per day, five days a week; and to write daily compliance diaries about stress reduction techniques practiced. Results from participants' diaries indicated that experimental participants practiced meditation 30 minutes per day, 3.5 days a week. The average of value and importance from this program was 9.3 out of 10. The findings showed that experimental group had significantly decreased psychological stress compared to the control group. The researchers concluded that participation in this eight-week meditation-based stress reduction program was effective in reducing psychological distress in a non-clinical population. However, mortality threat in this study is a concern not only limiting generalizability but also introducing bias (Fraenkel & Wallen, 1996).

Shapiro et al. (1998) reported study findings supporting the results of the above study. Researchers used an experimental design to investigate the effects of a mindfulness-based stress reduction (MSBR) program on psychological symptoms. Psychological stress was viewed as deleterious effects on one's physical and mental health. Participants included 78 premedical students who were randomly assigned to either an intervention group or a wait-list control group. Groups were matched for gender, race, and premedical vs. medical students. Participants in the intervention group were divided into two classes, which had different facilitators, but were equivalent. The intervention group practiced an eight-week Mindfulness meditation, which was a formal discipline that created awareness from moment to moment. In order to assess psychological stress, both intervention and control groups completed the Hopkins Symptom Checklist Revised (SCL-90) and State and Trait Anxiety (STAI-1) before and after intervention by an undergraduate research assistant. The findings indicated that the intervention group had significantly reduced anxiety and psychological distress compared to the control group. After first intervention, the same measures were assessed to the control group after participation in the intervention. The replicated findings showed that post intervention had significantly reduced anxiety and psychological distress compared to before practice. The intervention group employed different facilitators and the internal reliability of study questionnaires was not reported, thus casting doubt on the overall internal validity of the study.

Goleman and Schwartz (1976) reported similar results using a quasi-experimental design to assess the effectiveness of meditation in reducing stress reactivity. Transcendental meditation (TM) was used in the study as self-regulation of attention in order to reduce stress reactivity. Participants included a convenience sample of 30 experienced meditators with more than two years experience of TM and 30 nonmeditators (control group). The intervention was divided into four periods: baseline for four minutes, treatment for 20 minutes, a 5-minute post-treatment or rest, and a 12-minute film. In baseline period, all participants sat quietly and relaxed during looking at the blank video screen. In treatment period, participants within each sample group (meditator or control group) were randomly assigned to one of three conditions: meditation, relaxation with eyes open, or relaxation with eyes closed. The meditator group within the meditation condition was asked to perform TM, while the control group within the same condition was instructed in a simple TM technique. Participants in the meditator and control groups within the eye open condition were asked to keep their eyes on the screen and relax. Participants in meditator and control groups assigned within the eye closed condition were asked to relax and let their thought wander. The meditator group in this condition was told not to use a mantra. In post-treatment period, all participants were asked to open their eyes on the video screen. After that, all participants watched stressor film for 10 minutes and continually watched the blank screen for 2 minutes. All participants completed the State-trait Anxiety Inventory, which was not reported the internal reliability of the study, at baseline and post-stressor. The findings showed that the meditator group had significantly less state anxiety both before and after the stress intervention compared to the control group. Stressor recovery was significantly faster for the meditator group than the control group. Moreover, the meditator group reported more positive feelings and less anxiety than the control group before entering and after leaving the laboratory. However, when compared following treatment groups, the state anxiety of both meditator and control groups within meditation condition was not significantly different compared to either relaxation with eyes open or relaxation with eyes closed condition. This might cause that meditation condition or treatment effect was not enough to regulate stress situation as meditator group who had long term experienced in meditation practice. The researchers concluded that meditation was an effective method for improvement to stress reactivity.

Chang et al. (2004) also reported similar results of decreased psychological stress using a mindfulness-based stress reduction (MSBR) program. Researchers conducted a quasi-experimental design to examine the effects of MSBR intervention on perceived stress and mindfulness self efficacy. Forty-three participants from a private university continuing education course in the greater San Francisco Bay area participated in the study. Only 28 participants completed the follow-up measures. All participants were assessed for perceived stress using the Perceive Stress Scale 10-item version (PSS-10), which measured the perceived level of stress in the previous month; and mindfulness self-efficacy (MSE), which examined non-adjustment awareness during different situations, before and after the intervention program. The Cronbach's alpha coefficient for the PSS-10 and MSE were 0.86 and 0.84, respectively. The MSBR program of Kabat-Zinn and colleagues was used as the intervention. All participants practiced an eight-week mindfulness meditation, which was defined as the state of being aware of what was taking place. They were asked to practice 45 minutes for 6 days a week. The findings revealed that there were significant decreases in perceived stress scores and significant increases in MSE scores. The total score of PSS was negatively correlated with the total score of MSE, indicating that participants with higher levels of mindfulness self-efficacy experienced lower levels of perceived stress. However, the study should be considered within the data analysis since researchers included 43 participants into pre-treatment analysis while post-treatment calculation used the remaining participants of 28. Thus, there was a higher subject mortality rate limiting the generalizability (Fraenkel & Wallen, 1996).

Waelde et al. (2004) conducted a pilot study using a quasi-experimental design to examine the effect of an "inner resources" intervention (yoga, meditation, breathing techniques, guided imagery and mantra repetition) on dementia caregiver stress. Twelve female dementia patient family caregivers from the community participated in the study. Intensity anxiety was measured using the STAI, and depression using the Center for Epidemiological Studies Depression Scale (CES-D) at 1-week before intervention and at 1-month after treatment. The participants attended the 6-week intervention and were asked to practice at home at least 30 minutes per day for six days a week. The results revealed that the average minutes of weekly yoga-meditation practice were significantly correlated with decreased depression. There were significant reductions of anxiety and depression. The researchers concluded that the inner resource intervention was helpful for improvement of anxiety and depression. A small sample in the study should be limited the generalizability.

In contrast to the above findings, Robinson et al. (2003) used a quasi-experimental design to examine the effect of a MBSR program on perceived stress in patients with human immunodeficiency virus (HIV) infection. Depending on their interest to participate in the intervention group, participants from multiple HIV service agencies were divided into MBSR (n = 46) or control groups (n = 10), The MBSR intervention was conceptualized as an effort to focus attention on self-observation and moment to moment of awareness. Participants were required to complete at least six of the eight weekly sessions of MBSR program. Perceived stress was measured by the PSS-10 before and after the intervention. The alpha coefficient of the PSS-10 in this study was 0.85. Only 24 of the 46 MBSR participants completed the intervention and an intent-to-treat analysis was not used. The perceived stress scores of the MSBR group were not significantly different compared to either within group or control group. This insignificant finding might result from a small sample size. While researchers reported that a power analysis was used to calculate the desired sample size, the power calculation completed after the study was indicated that the power was not sufficient to find within group changes or between group differences (Robinson et al., 2003). In addition, participants who completed the intervention had a significantly lower perceived stress than non-completers at baseline. Non-equivalent groups are a source of concern to the validity of the findings, as is the high mortality rate (Fraenkel & Wallen, 1996) and the small sample size.

In summary, six studies were reviewed on the effect of meditation on psychological stress. Most study outcomes indicated that meditation significantly reduced psychological stress. Only one study revealed no effect on psychological stress. The studies had a range of threats to internal and external validity in terms of implementer, mortality effects and small sample size.

Effect of Meditation on Heart Rate Variability

The literature was also reviewed on the effects of meditation on HRV and a total of six studies were identified (Cysarz & Bussing, 2005; Matzner, 2003; Murata et al., 2004; Peng et al., 1999; Peng et al., 2004; Takahashi et al., 2005). Participants were either experienced meditators (Cysarz & Bussing, 2005; Matzner, 2003; Peng et al., 1999; Peng et al., 2004), healthy persons (Peng et al., 1999; Murata et al., 2004), or students (Murata et al., 2004; Takahashi et al., 2005). Two studies revealed significantly increased LF power in meditators (Cysarz & Bussing, 2005; Peng et al., 2004), while one study revealed significantly decreased LF power (Takahashi et al., 2005) and another one showed insignificantly decreased LF power (Murata et al., 2004). Most studies documented significantly increased HF power (Murata et al., 2004; Peng et al., 1999; Peng et al., 2004; Takahashi et al., 2005), except Cysarz & Bussing (2005). One study reported unchanged LF/HF ratio (Peng et al., 2004), while others revealed significantly decreased (Murata et al., 2004; Takahashi et al., 2005), or significantly increased LF/HF ratio (Cysarz & Bussing, 2005). The summarized findings are shown in Table 5. The details for each study are described below.

Table 5

Effects of Meditation on Heart Rate Variability

Author	Research design/ Sample	Statistical findings		
		LF power	HF power	LF/HF ratio
Matzner (2003)	Quasi-experimental study/ 4 experienced meditators	Increased*	Not reported	Not reported
Cysarz & Bussing (2005)	Quasi-experimental study/ 2 meditators and 7 non-meditators	Increased	Decreased	Increased
Peng et al. (1999)	Quasi-experimental study/ 12 experienced meditators	Not reported	Increased	Not reported
Peng et al. (2004)	Quasi-experimental study/ 10 experienced meditators	Increased	Increased	Unchanged
Murata et al. (2004)	Quasi-experimental study/ 22 undergraduate students	Decreased (*ns*)	Increased	Decreased
Takahashi et al. (2005)	Quasi-experimental study/ 20 undergraduate students	Decreased	Increased	Decreased

Note. LF = Low frequency. HF = High frequency. *ns* = Nonsignificant.

* Researcher did not report significant finding or not.

Matzner (2003) used a quasi-experimental design to examine the effect of meditation on HRV. Four kundalini yoga mediators had HRV recorded during resting and meditating periods using chanting and breathing exercises for 15 minutes each. The study did not report either how to measure heart data or what equipment was used to collect heart data. However, researcher used the Blackman-Tukey method to decrease the variance of the natural estimator before transformation into the frequency domain. The findings revealed that the total power of HRV increased during the meditation period compared to the resting period. Additional power appeared in the LF power (0.04−0.15 Hz). The researcher concluded that a change in the balance of the ANS quantified by an increase in LF power was induced by meditation (Matzner, 2003). However, there was no reporting of whether the findings were statistically significant and the small sample size should be considered. The study also did not report how heart data were collected; thus, there were several threats to internal validity (Fraenkel & Wallen, 1996).

Cysarz and Bussing (2005) also used a quasi-experimental design to examine the effect of zen meditation on HRV. Meditation was viewed as a traditional exercise with a potential on well-being and health. Two experienced meditators and seven non-meditators participated in the study. All participants had ECG recorded using solid state recorder (Medikorder MK2, Tom-Signal, Graz, Austria) during six different experimental procedures: sitting on a chair, mental task, zazen (sitting) meditation, kinhin (walking) meditation, zazen meditation, and sitting on a chair. The two sitting periods and the two periods of zazen meditation were averaged. Thus, four different procedures were compared. Heart rate data were analyzed using Fast Fourier Transformation resulting in power spectral density distribution: LF power and HF power. The findings showed that HF power during kinhin meditation significantly decreased compared to sitting period, mental task, and zazen meditation. However, LF power and LF/HF ratio during zazen and kinhin meditation significantly increased compared to sitting period and mental task. The researchers concluded that prior experience in meditation was not required to experience the physiological changes associated with meditation. Though the results had significant physiological changes, the small sample size in this study is a concern.

Peng et al. (1999) reported a different outcome with respect to HF power. Researchers used a quasi-experimental design to investigate any distinctive heart rate (HR) dynamics during meditation practices and any pattern of autonomic response induced by meditative states. Eight novice qigong meditators and four experienced kundalini yoga meditators participated in the meditation group. The qigong group had ECG recorded using Holter recordings approximately 10 hours during ordinary daily activities. In this period, the qigong group was assigned to meditate for one hour at the fifth hour of ECG recording. Kundalini yoga meditators wore a Holter monitor for approximately one and a half hours. They had ECG recording 15 minutes of baseline and one hour of meditation. Heart data were analyzed using Fourier spectral power in the frequency range 0.025−0.35 Hz. The researchers also compared HF power between the meditator group and three healthy control groups. The control groups were drawn from a database of retrospective ECG recordings. The control groups included a healthy group of 11 participants during spontaneous nocturnal breathing, a healthy group of 14 participants during metronomic breathing, and a group of 9 elite triathlon athletes during sleeping. The findings showed both meditation groups had significantly higher HF power compared to their pre-meditation baseline and to the control groups. The findings suggested that meditation can increase HRV (Peng et al., 1999). However, there was not congruence between the data collection protocols for the intervention and control groups, thus contributing to non-equivalent data sets for comparison.

A related study was carried out by Peng et al. (2004). The researchers used a quasi-experimental design to compare instantaneous HR dynamics and cardiopulmonary reactions during three forms of meditation. A total of 10 experienced kundalani yoga meditators had ECG measured, as well as recordings of respiration signals using a DigiTrace 1800 SL recorder (SleepMed, Boston, MA). Heart data were collected during three meditation approaches characterized by different breathing patterns, including relaxation response, breath of fire (rapid breath about 140/ minute), and bilateral segmented breathing (breath divided into eight equal steps on each inhalation and exhalation). Participants served as their own controls, each using all three of these breathing patterns. Each meditation period lasted approximately 10 minutes and followed with a control period of equal duration. Heart data were analyzed its Fourier spectral power using the Lomb technique in three frequency bands: total power (0−0.4 Hz), HF power (0.15−0.4 Hz), and LF power (0.04−0.15 Hz). The HF/LF ratio was also calculated. The findings revealed that total power of HRV and HF/LF ratio were not significantly different among the three meditation protocols. The breath of fire period showed significantly reduced LF power and HF power compared to the relaxation response and segmented breathing. The researchers concluded that different meditative technique may affect heart rate as well as specific responses (Peng et al., 2004).

In contrast to the above outcomes related to LF power and LF/HF ratio, Murata et al. (2004) also used a quasi-experimental design to examine the effect of zen meditation on HRV. Twenty two undergraduate students without experience of any meditation practice were participants in the study. All participants had ECG signals recorded using FM 300 Holter monitoring (Fukuda-Denshi, Tokyo, Japan) during control conditions for 15 minutes and during a su-soku meditation for 15 minutes. su-soko meditation is a zen meditation practice for concentrating the mind by silently counting one's breath. In the control condition, the last 5-minute period of the 15-minute recording was analyzed HRV. In the meditative condition, the 15-minute period was divided into three 5-minute interval, and the interval, which each participant reported that it had the most concentration was used as analysis period. Power spectral analysis of HRV was calculated with a Fast Fourier technique using a Hamming window (Fukuda-Denshi Co.). Spectral components were identified on the basis of their frequencies into three bands: very low frequency power (0 − 0.03 Hz), LF power (0.04−0.15 Hz), and HF power (0.16−0.45 Hz). The LF power corresponded to baroreflex control of HR and reflected mixed sympathetic and parasympathetic activities, while HF power corresponded to vagally mediated modulation of HRV. The findings revealed significantly increased HF power and decreased LF/HF ratio during meditation period compared to control condition. There was no significantly decreased LF power compared to control condition. However, the study findings may have an implementer threat (Fraenkel & Wallen, 1996) due to using different period of treatment to analyze HRV.

Takahashi et al. (2005) supported the study findings of Murata et al. Researchers used a quasi-experimental design to examine the effect of zen meditation on HRV. Meditation was defined as the mental activity associated with attainment of a restful but fully alert state. Twenty undergraduate students who had no experience of any meditation practice participated in the study. All participants had HRV recorded using the same equipment and procedure as Murata et al. (2004). Similarly, in the control condition, the last 5-minute period of the 15-minute recording was analyzed HRV. In the meditative condition, the 15-minute period was divided into three 5-minute interval, and the interval, which each participant reported that it had the most concentration was used as analysis period. The findings revealed significantly decreased LF power and LF/HF ratio during the meditation period compared to the control condition, while showed significantly increased HF power during meditation practice compared to control condition. The study findings may have an implementer threat (Fraenkel & Wallen, 1996) due to using different period of treatment to analyze HRV.

In summary, a consistent pattern of HRV response to meditation was not demonstrated in the six studies reviewed. However, the studies had consistently small sample sizes and there were data collection procedures which contributed to non-equivalent data sets. Some studies should be also considered the implementer and instrumentation threat.

Effects of Meditation on Blood Pressure

A total of six studies were located on the effects of meditation on BP (Barnes et al., 1999; Barnes et al., 2001; Barnes et al., 2004; Solberg et al., 2004; Sudsuang et al., 1991; Wallace et al., 1983). Study samples included meditators (Barnes et al., 1999; Solberg et al., 2004; Wallace et al., 1983) and non-meditators (Barnes et al., 1999; Barnes et al., 2001; Barnes et al., 2004; Solberg et al., 2004; Sudsuang et al., 1991). The findings indicated that there were inconsistent effects of meditation on both systolic and diastolic BP as noted in Table 6. The details for each study will be described below.

Table 6

Effect of Meditation on Blood Pressure

Author	Research design/Sample	Statistical findings	
		Systolic BP	Diastolic BP
Solberg et al. (2004)	Cross-sectional comparative study/ 44 meditators and 30 non-meditators	Unchanged	Unchanged
Wallace et al. (1983)	Cross-sectional study/ 112 meditators	Decreased	Not studied
Barnes et al. (1999)	Quasi-experimental study/ 18 meditators and 14 healthy adults	Decreased	Unchanged
Barnes et al. (2001)	Experimental design/ 35 adolescents	Decreased	Decreased (*ns*)
Barnes et al. (2004)	Experimental design/ 100 adolescents	Decreased	Decreased (*ns*)
Sudsuang et al. (1990)	Experimental design/ 52 male students	Decreased	Decreased

Note. BP = Blood pressure. *ns* = Nonsignificant.

Solberg et al. (2004) used a controlled cross-sectional comparative design to examine hemodynamic changes during long meditation. The volunteer participants included only men who were either meditators (n =44) or non-meditators (n = 30). Meditators performed ACEM meditation for three hours. ACEM meditation, which was taught and explained in psychophysiological terms, was a method for relaxation and inner strength. The control group was instructed to sit or rest as they preferred, but avoid talking, sleeping or working for one hour. All participants had BP measured using an automatic equipment (DINAMAD XL Vital Signs Monitor) before and after three hours of meditation, and one hour of rest period in control group. The findings revealed insignificantly changed systolic and diastolic BP within each group during either meditation or rest period. The lack of significant findings might have resulted from lack of the power analysis to detect the expected difference within groups. An implementer threat should be considered since both groups had different periods of intervention. The reliability of the BP measurement should be a concern, given that there was no report of instrument standardization procedures (Fraenkel & Wallen, 1996).

Wallace et al. (1983) reported different results from Solberg et al. (2004). Researchers used a cross-sectional design to examine the effect of meditation on systolic BP. Participants, who were recruited from the Maharishi International University in Fairfield, Iowa, included 112 meditators who had practiced transcendental meditation (TM) for one to 180 months. In those who practiced TM, 42 meditators also practiced advance TM-sidhi program. All participants had systolic BP measured using a standard mercury sphygmomanometer. Three readings were taken on each of two consecutive days. Average BP data of meditators were compared to systolic BP data from population normative data, which were similar for gender, race, and education to meditator group. The findings showed a significant lower systolic BP compared to the population means derived from the U.S. Department of Health and Welfare publication. Those practicing meditation greater than five years had a significantly lower systolic BP than those practicing meditation less than five years. The researchers concluded that the long-term practice of TM and TM-Sidhi had beneficial effects on systolic BP (Wallace et al., 1983).

Barnes et al. (1999) used a quasi-experimental design to test the effect of transcendental meditation (TM) on BP. Participants included 18 long-term practitioners of TM, who were recruited at the Maharishi Ayur-Veda School in Atlanta, Georgia, and 14 healthy control participants, who were recruited among parents of youth participating in a longitudinal study of cardiovascular health or from the Medical College of Georgia. All participants completed the eyes-open rest condition for 20 minutes. The TM participants performed meditation for 20 minutes, while the control participants completed a 20-minute eyes-closed relaxation condition. All participants had BP recorded using Dinamap Vital Signs Monitor (model 1846SX, Critikon, Inc.,Tampa, FL) before and every five minutes during each 20-minute condition (eyes-open rest, TM, and eyes-closed relaxation).These BP measurements were averaged to provide one measurement for each condition. The results showed that the TM group during eyes-open rest condition had significantly reduced systolic BP compared to the control group with the same condition. In addition, the TM group during the meditation condition displayed a significant decrease in systolic BP compared to the control group during their eyes-closed relaxation period. However, diastolic BP was not significantly different between TM group during meditation condition and control group during eyes-closed relaxation period. The researcher concluded that TM had an effect on reduced systolic BP (Barnes et al., 1999). The reliability of the BP measurement should be considered, given that there was no report of instrument standardization procedures.

Two years later, Barnes et al. (2001) used an experimental design with the same purpose as the previous study, using a different sample. Thirty five students at an inner city school were randomly assigned to either a TM or a control group. The TM group performed meditation, which was a simple mental procedure, for 15 minutes twice a day for 2 months. The control group was presented with seven weekly one-hour lifestyle education sessions. All participants had BP measured using Dinamap Vital Signs Monitor (model 1846SX, Critikon, Inc., Tampa, FL) at pretest and posttest. Blood pressure was measured twice and was averaged to provide one measurement for each BP evaluation: at rest and in responses to two laboratory stressors. The acute stressful situations were a stimulated car driving stressor and a social interview. The findings showed that the TM group had significantly reduced systolic BP in resting period and in response to two laboratory stressors from pre-intervention to post-intervention compared to the control group. The TM group also had lower diastolic BP in each condition compared to the control group, but the difference was not statistically significant. The researcher suggested that TM had beneficial effects on systolic BP (Barnes et al., 2001). There was no documentation of instrument standardization procedures. Thus, the reliability of the BP measurement is uncertain.

Barnes et al. (2004) used an experimental design to determine the impact of stress reduction using TM on BP in African-American adolescents with high normal systolic BP. All participants were randomly assigned by school to either 4-month TM group (n = 50) or health education control (n =50) group. The TM group practiced TM technique for 15 minutes twice a day. The control group was taught a 4-month didactic series of 15-minute lifestyle education based on the National Institutes of Health guidelines on lowering BP. Ambulatory 24-hour BP was recorded using the Spacelabs ambulatory BP monitor 90207

(Spacelabs, Inc., Redmond, WA) at pretest, 2- , 4-, and 8-month post-tests. The findings showed that the TM group had a significantly lower systolic BP in daytime compared to the control group. There were no significant differences in diastolic BP between both groups. The researchers concluded that the findings demonstrated a beneficial impact of TM program on BP (Barnes et al., 2004). According to no report of instrument standardization procedures, the reliability of the BP measurement is questionable.

Sudsuang et al. (1991) used an experimental design to test the effect of dhammakaya meditation on BP in male college Thai students. The experimental group consisted of 52 male college Thai students practicing the dhammakaya meditation and staying in the monastery as monks for 2 months without other activities except walking to receive food from people in the morning. Dhammakaya meditation which was a method of Samadhi meditation, referred to concentration of mind and thoughts upon a round glass ball object, free from all traces of wavering and distraction. A control group included 30 males who were non-meditating college students of the same age as the experimental group but lived at home. Both groups had BP recorded at the beginning, at three and at six weeks of the program using a standard mercury sphygmomanometer. The findings showed that in the experimental group, systolic and diastolic BP significantly decreased after three and six weeks of the program. Also, the experimental group had significantly lower systolic and diastolic BP as compared to the control group at three and six weeks of the program. Researchers concluded that Buddhist meditation induced reduction of BP.

In summary, six studies were located that documented the effects of meditation on BP. Five out of six studies found that meditation significantly reduced systolic BP and one study indicated a significant decrease in diastolic BP. The studies had a range of threats to internal and external validity in terms of implementer, instrumentation, and small sample size.

Relationships among Psychological Stress, Blood Pressure, Heart Rate Variability, and Meditation Practice

A total of 30 articles were reviewed in order to provide current information with respect to the variables of interest and their relationships to each other. However, there were no studies located which simultaneously examined relationships among psychological stress, BP, HRV, and meditation practice. Thus, their relationships to each other are unclear. This study was indicated to clarify their relationships.

Summary

A total of 30 articles were reviewed to determine what was known about the relationships among stress, BP, HRV and meditation practice. The findings of early studies documented the inconsistent effects of psychological stress on either BP or HRV. Furthermore, previous studies reported the inconsistent effects of meditation on psychological stress, BP, or HRV. Additionally, there were no studies located which simultaneously examined relationships among psychological stress, BP, HRV, and meditation practice. Some studies did not control threats to internal validity in terms of instrumentation, implementation, or mortality effects.

Implications for Current Study

This study used a cross-sectional descriptive-correlational design to simultaneously examine the relationships among variables of interest, which included stress, BP, HRV, and meditation practice. The study included several methods to control threats to validity in terms of instrumentation and implementation effects, to ensure accuracy of measurement and to ensure an adequate sample size. They included: a) clearly defined conceptual and operational definitions; b) clearly outlined procedures for systematically collecting data; c) a power analysis to ensure an adequate sample size; d) calibration of BP equipment and maintenance of a Log-a-Rhythm® Model 100 according to the manufacturer's specification, and e) methods to ensure that there was no missing data. These procedures are described in Chapter 3.

Chapter 3

Research Methods

This study examined the relationships among perceived stress, blood pressure (BP), and heart rate variability (HRV) in meditators. The overall goals of this study were to evaluate the relationships between perceived stress and reactivity of the autonomic nervous system (ANS) as observed by BP and HRV, as well as the relationships between meditation practice and perceived stress and reactivity of the ANS as assessed by BP and HRV. It was hypothesized that: (1) perceived stress had a positive correlation with BP and low frequency (LF) power, and an inverse correlation with high frequency (HF) power in meditators; and (2) meditation practice had a negative correlation with perceived stress, BP, and LF power, and a positive correlation with HF power in meditators. Information from this study will provide preliminary data for future work focused on stress management using meditation approaches to reduce risk for cardiovascular diseases. This chapter includes the results of a feasibility study and addresses the research methods, including research design, setting, sample selection and sample size, measurement of variables, data collection and procedures, human subjects protection, data management and data analysis for the study.

Pilot Study

To prepare for this study, a pilot study was conducted in 2004 to evaluate the feasibility of study procedures. Two healthy women who regularly performed meditation participated in the feasibility study. After sitting in a relaxed position for 5 minutes, each participant's BP was measured by the researcher using an aneroid sphygmomanometer and stethoscope. Next, three electrodes of the Log-a-Rhythm® Model 100 were placed on the chest and ribs. All electrodes were connected by standard lead wires to a Signal Acquisition Unit of the Log-a-Rhythm to obtain a continuous recording of the heart beat interval before meditation for 5 minutes, during meditation for 10 minutes, and after meditation for 5 minutes. Then, BP was measured after measuring HRV and both the demographic data form and 10-item version of the Perceived Stress Scale were completed by each participant.

The mean PSS score was 16.50 indicating moderate stress. Both mean systolic and diastolic BP after meditation were less than before meditation. Low frequency power of HRV was lowest before meditation, while HF power was highest during the same period. During meditation LF power was highest, while HF power was lowest. The LF/HF ratio was higher during meditation and after meditation than before meditation.

Study procedures were deemed feasible based on ease of data collection, ability of the investigator to obtain all measurements with equipment and the ability to obtain recordable data. Based on very limited data from only two people, it was possible that the research procedure actually induced stress and that the meditation interval was not sufficiently long. As a result of the findings, the procedures for this study were modified to include a longer meditation period, more closely approximating typical meditation intervals. It was decided that all questionnaires would be completed before other procedures in order to reduce effects of any stress perceived related to the research study procedures.

Research Design

A cross-sectional descriptive-correlational design was used to test the research hypotheses. The correlational research design was suitable for this study because it was a non-intrusive observational study that described participants as they existed in their usual settings. There was no manipulation of variables, and measurements were taken at one point in time. The design was used to efficiently and effectively collect data about a problem area in order to investigate the strength of relationships among variables prior to developing and testing experimental designs (Crotty, 1998; Fraenkel & Wallen, 1996; Polit & Hungler, 1997; Talbot, 1995).

The philosophical and theoretical underpinnings of a correlational research design are based on objectivism and positivism. In this perspective, the phenomena of study are observed in a natural setting, controlling conditions in order to rule out specific intervening variables. The researcher structured the situation by identifying and isolating variables for study, and by employing specific measurements and instruments to collect data on these variables. Thus, the phenomena of study could be operationalized using systematic methods and statistical analysis in order to explore relationships among phenomena (Crotty, 1998; Polit & Hungler, 1997; Talbot, 1995).

Setting

The study was conducted at Ekoji Buddhist Sangha of Richmond and Still Water Zen Center. Ekoji Buddhist Sangha of Richmond is located at 3411 Grove Avenue, Richmond, Virginia. This center was founded in 1986 by Reverend Kenryu Tsuji, a Japanese-American Pure Land Buddhist priest, in order to support teaching, practice and study of Buddhism in the Greater Richmond area. Ekoji Buddhist Sangha of Richmond operates as a non-profit religious organization and serves as a gathering place for Buddhists from several different practices. Within a single temple, groups representing the Pure Land, Soto Zen, Tibetan Karma Kagyu, and Vipassana lineages of Buddhism have sought refuge together as a single sangha, yet each group maintains its own traditional forms of practice (Wilson, 2003).

Pure Land Buddhism is the oldest form of organized Buddhism in the United States. Fundamental to this tradition is the promise of enlightenment implicit in Amida Buddha's pledge that the Pure Land is accessible to all by means of repetition of his name. The group activities are centered on the practices of chant and meditation. They also conduct informal sutra study and discussion. The group meets for service in the large room on the first floor on Saturdays between 2:00 and 4:00 pm.

In 1991, the Richmond Zen Group and the Chimborazo Zen Group established at the Ekoji Buddhist Sangha of Richmond to form the Ekoji Zen Group. The group name was recently changed back to Richmond Zen Group. Zen practice emphasizes zazen, or seated meditation, as the primary means to realize the teachings of Buddha. Zen practice includes walking meditation (kinhin), bowing, and chanting. Practice also extends into everyday activities such as eating and working. The spiritual director for the Zen group is Taitaku Pat Phelan, Abbot of the Chapel Hill Zen Center in North Carolina. Chapel Hill and Richmond Zen groups practice soto zen in the lineage of Shunryn Suzuki Roshi, founder of the San Francisco Zen Center. The group meets in the large room on the first floor on Wednesday evenings between 6:45 and 8:30 pm, Friday mornings between 6:30 and 8:00 am, and Sunday mornings between 8:45 and 10:30 am.

Next to appear at the Ekoji Buddhist Sangha of Richmond was a Karma Kagyu (a type of Tibetan Buddhism) group, which was started in 1993 by several members. The ultimate aim of this group is to perfect wisdom and compassion through the religious practices. Tibetan Buddhism emphasizes chanting. Practices also include meditation and mantra. The group is affiliated with Lama Norlha Rinpoche, an immigrant from Tibet and founder of Kagyu Thubten Choling Monastery in the state of New York. This group meets in the Tibetan room on the second floor between 7:30 and 9:30 pm. on Tuesday nights.

The Vipassana group started meeting at the Ekoji Buddhist Sangha of Richmond in 1995. This group practices vipassana meditation and studies Buddhist teachings based on the Theravada tradition of Buddhism popular in Southeast Asia. The group sponsors visits by several different Theravada teachers to lead retreats. The group meets in the large room on the first floor on Mondays between 7:30 and 8:30 pm and on Fridays between 5:30 pm and 7:30 pm.

Still Water Zen Center is located at 1004 N. Thompson Street, Suit 300 in Richmond, Virginia. This center offers korean and rinzai zen meditation practices, training, and retreat. A resident teacher is Honji Osho. Honji founded this center in 1999, and received Inka from Zen Master Dae Gak of Furnace Mountain in Kentucky in 2005. Still Water Zen Center is affiliated with the Furnace Mountain Sangha in Kentucky. Zen Master Dae Gak regularly visits this center to lead retreats. Still Water Zen Center operates as a non-profit religious organization. This center is supported by donations and event fees. The group activities are centered on practices of chanting, sitting and walking meditation. The group meets at a Dharma room on Wednesdays between 7:30 and 8:00 am, and between 7:00 and 8:30 pm, and on Sundays between 10:00 and 12:00 am.

All data collection, including completion of informed consent procedures, took place in a quiet room either on the second floor of Ekoji Buddhist Sangha of Richmond or in the Dharma room of Still Water Zen Center, depending on the site used by participants for meditation practice. Both rooms were designated for the use of the researcher to conduct the study.

Sampling and Sample Size

Sample Selection

People who had practiced meditation for any length of time and who practiced sitting meditation at one of the study sites were recruited for the study. The experienced meditator was defined as a person who performed meditation at least three times a week for one year or more (Compton & Becker, 1983; Delmonte, 1985; Bonadonna, 2003). Inclusion criteria included being self-identified as an adult (18 years of age or older), a healthy person not on antihypertensive or other cardiac medication, having a regular meditation practice, and having the ability to understand, speak, read and write in the English language.

Sample Size Determination by Power Analysis

In using a correlational research design, the sample size should be large enough to reveal meaningful findings and to decrease the risk of a Type II error which occurs when one wrongly accepts a false null hypothesis. A power analysis was calculated as follows (Polit, 1996, p. 230):

$$N = \left(\frac{\delta}{r}\right)^2 + 1$$

$$= \left(\frac{2.5}{0.3}\right)^2 + 1 = 71$$

δ = tabled value (2.5) for a one-tailed significance (α) = .05, and a power of .80 (Polit, 1996, p. 482), and

R = medium effect size = 0.3 (Cohen, 1988, p. 83).

A medium effect size of 0.3 was selected because the researcher expected that meditation practice had a moderate correlation with perceived stress, BP, and HRV (Cohen, 1988, p. 83). Therefore, the desired sample size was 71.

Data Collection and Procedures

Recruitment and Enrollment

Recruitment of participants at the Ekoji Buddhist Sangha of Richmond was initially approved by the Institutional Review Board (IRB) of Virginia Commonwealth University (see Appendix A). Participants were recruited via the use of advertising posters placed on the message board at the center. Meditators who were interested in the study were invited to contact the researcher via telephone or email. They could also complete a sign-up document at the center and the researcher subsequently contacted them via telephone or email. The researcher also recruited participants directly by regularly visiting the center, explaining the study, and asking those who attended to participate in the study.

Participant enrollment at the Ekoji Buddhist Sangha of Richmond was not sufficient to meet sample size requirements. However, an additional recruitment site, the Still Water Zen Center, was approved as a recruitment site by the VCU IRB (see Appendix A) and previously described recruitment procedures were replicated in that site. For those who were interested in either site, eligibility and willingness to participate were established, information about the study was shared, and an appointment was made in order to complete written informed consent documents and collect data.

Procedures

The researcher collected data in a quiet room in each center, which was designated for use by the researcher. The human subjects protection procedures and data collection for each participant required approximately 50 minutes and included the following elements:

1. The researcher provided a participant an oral explanation as well as a written informed consent document (Appendix B).

2. After informed consent was obtained, the participant was asked to complete the Meditation Practice Questionnaire, the perceived current stress visual analogue scale, the Perceived Stress Scale, and a demographic form.

3. Then, the participant sat in a relaxed position for 5 minutes. Blood pressure was measured by the researcher using an automatic BP device (Omron HEM-705CP) with an appropriate arm cuff applied to the participant's left arm, about 2.5 centimeters above the antecubital space (Ralstin, 2000). Two BP readings, approximately one minute apart, were taken by the researcher before meditation. The BP cuff remained on the participant's arm until the post-meditation BP measurement.

4. Next, electrodes of the Log-a-Rhythm® Model 100 were placed at the right shoulder, the clavicle, two left ribs, and right lower abdomen, for a total of 5 electrodes. All electrodes were connected by standard lead wires to a Signal Acquisition Unit of the Log-a-Rhythm to obtain a continuous recording of the heart beat interval.

5. The participant then meditated for 30 minutes while the heart beat interval was recorded. The researcher used a chime to signal the beginning and the end of meditation practice. While the participants were meditating, the researcher reviewed all questionnaires to ensure that all questions were answered completely.

6. Blood pressure was recorded immediately following the conclusion of the meditation practice, using the same procedure as outlined above. Upon completion of the second BP measurement, all electrodes and the BP cuff were removed from the participant. Any missing information was obtained following the final BP measurement.

Measurement of Variables

Four major variables were measured: meditation practice, perceived stress, BP, and HRV. Demographic data were also obtained to provide general information about the study sample. Each variable is described in more detail in the following sections and the specific methods of measurement and level of each variable are displayed in Table 7.

Meditation Practice

A Meditation Practice Questionnaire was constructed by the researcher to quantify the usual patterns of meditation practice. The questionnaire asked about type, length, frequency, and session duration of meditation practice. This questionnaire is provided in

Table 7

Measurement and Its Level of Each Variable

Variables	Instrument	Level of measurement
Meditation practice:	Meditation Questionnaire	
Type		Nominal
Length, frequency, and duration		Continuous
Perceived stress		
Perceived current stress	Visual analogue scale for perceived current stress	Ordinal
Perceived stress (Past month)	PSS-10*	Ordinal
Blood pressure:	Omron model HEM-705CP**	
Systolic		Continuous
Diastolic		Continuous
Heart rate variability:	Log-a-Rhythm® Model 100	
LF power		Continuous
HF power		Continuous
Demographic information:	Demographic Form	
Gender		Nominal
Age		Continuous
Race		Nominal
Religion		Nominal
Education		Nominal
Regular use of any medicine		Nominal

Note. * PSS-10 = 10-item version of Perceived Stress Scale (Cohen & Williamson, 1988).

** Omron model HEM-705CP is automatic sphygmomanometer. LF = Low frequency. HF = High frequency.

Appendix C. The questionnaire was reviewed by the Board of Directors of the Ekoji Buddhist Sangha of Richmond, to ensure content validity.

Perceived Stress

Perceived stress in this study was measured using two approaches: a visual analogue scale for perceived current stress and the 10-item version of the Perceived Stress Scale (PSS-10). These two approaches provided an assessment of perceived stress of participants in the present and in the past month (see Appendix C).

Perceived current stress. A visual analogue scale for perceived current stress was constructed by the researcher to assess the level of perceived stress at the time of data collection. The question, "How stressed are you feeling right now?" was answered using a 10-point visual analogue scale ranging from 1 to 10, with higher scores indicating higher levels of perceived stress in the present. The single score measure of perceived current stress was reviewed by the Board of Directors of the Ekoji Buddhist Sangha of Richmond to ensure content validity.

Perceived Stress Scale. Participants' perceived stress was also measured by the 10-item version of the Perceived Stress Scale (PSS-10), constructed by Cohen and Williamson (1988). The PSS-10 was derived from the original scale, the PSS 14-item version, which was the most widely instrument used for measuring stress perception (Cohen, et al., 1983). The PSS-10 was based on Lazarus and Folkman's concept of cognitive appraisal (Cohen, et al., 1983). This instrument measures the degree to which situations in one's life are appraised as stressful. It was designed to tap how unpredictable, uncontrollable, and unmanageable respondents find their lives. The questionnaire asks about feelings and thoughts during the last month. The PSS-10 has a 5-point Likert scale ranging from "never" to "very often." Scores ranged from 0 to 40, with higher scores indicating higher levels of perceived stress.

The PSS-10 provides an adequate measure of perceived stress in an adult population in the United States. The PSS-10 has been used in many studies in various adult populations, all consistently documenting an internal consistency at or above 0.90 (Dennis, 2002; Kalpakjian, Toussaint, Quint, & Reame 2005; Miller, Cohen, & Ritchey, 2002; Stowell, Kiecolt-Glaser, & Glaser, 2001). In two different studies of the effects of mindfulness-based stress reduction programs, the PSS-10 had an internal consistency 0.85 or higher (Chang et al., 2004; Robinson et al., 2003). The standardized alpha reliability of the PSS-10 in this study using Cronbach's alpha was 0.81.

Blood Pressure

Blood pressure was measured using a digital BP measurement device, the Omron model HEM-705CP automatic sphygmomanometer. This device was recommended by the European Society of Hypertension (O'Brien, Waeber, Parati, Staessen, & Myers, 2001), based on the criteria of the Association for the Advancement of Medical Instrumentation (AAMI) and the British Hypertension Society (BHS). The device uses the oscillometric technique and automated inflation and deflation of a cuff applied to the upper arm over the brachial artery. Thus, the monitor detects blood's movement through the brachial artery and converts the movements into a digital reading displaying systolic and diastolic BP in mmHg unit on a display panel. The accuracy of this device is plus or minus 4 mmHg compared to a mercury standard. Both systolic and diastolic BP were measured as continuous variables. The detailed specifications of the Omron model HEM-705CP automatic sphygmomanometer are shown in Appendix D.

Heart Rate Variability

Heart rate variability was measured using the Log-a-Rhythm® Model 100 (Newby & Craelius, 2003). The Log-a-rhythm signal acquisition unit, which uses conventional electrocardiograph (ECG) monitoring techniques, recorded consecutive heart beat intervals for 30 minutes during meditation practice in this study. The ECG data were digitized and RR intervals stored by this unit with a resolution of 4 milliseconds (ms). Using the Log-a-Rhythm® Heart Rate Analysis Software, developed by Nian-Crae, Inc., the heart rate recording segments were analyzed using a Fast Fourier technique to calculate the area under each power spectrum of HRV. This study used two main spectral components, LF power and HF power in normalized units (n.u.). Normalization is obtained by dividing the absolute power of each component by the total power within a range of 0.04 and 0.5 Hz and multiplying by 100 (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrotophysiology, 1996). In beat detection mode, this instrument was greater than 99% consistent with the American Heart Association ECG Database (Nian-Crae, Inc., NJ). Detailed information about the Log-a-Rhythm® Model 100 is displayed in Appendix E.

Demographic Information

A demographic form (Appendix C) was constructed by the researcher to record the demographic background of participants. The form included information on gender, age, race, religion, education and regular use of any medication.

Human Subjects Protection

The Office of Research Subjects Protection at Virginia Commonwealth University (VCU) approved this research under the direction of D. Patricia Gray, RN, Ph.D. (see VCU Institutional Review Board (IRB) # 5058 dated July 26, 2005 in Appendix A). Because the number of subjects recruited at the Ekoji Buddhist Sangha of Richmond was insufficient to achieve the desired sample size of 71, an additional site, Still Water Zen Center, was approved by the IRB for recruiting participants and collecting data on November 4, 2005 (see Appendix A). In compliance with the IRB procedures, the researcher recruited and enrolled volunteer meditators at both the Ekoji Buddhist Sangha of Richmond and the Still Water Zen Center. Participants were provided an oral explanation as well as written information sheet explaining the nature of the study, requirements of participation, rights, and safeguards to confidentiality, and contact information for the investigator and IRB. Participants were fully informed of the procedures and information required for the study, and each voluntarily completed the informed consent document.

In this study, there was no reimbursement for participating and participants were not expected to receive any direct medical benefits from participation in the study, except receiving BP assessment. Some participants had some slight discomfort during the recording of BP and heart rhythm data. Some also had numbness after meditation practice, which was not an unusual experience for them. However, there were no serious adverse reactions during data collection procedures. The information obtained in this study was kept strictly confidential, and it was not possible to identify any individual participant.

Each participant was assigned an arbitrary code number to ensure anonymity of the research data.

Threats to Internal Validity

In a correlational study, a researcher should be concerned about threats to internal validity for relationships found in the data. Fraenkel and Wallen (1996) suggested 10 threats to internal validity important to interventional studies: subject characteristics, location, instrumentation, testing, mortality, history, maturation, attitude of subjects, regression, and implementation. Threats to internal validity that could apply in correlational research designs are as follows:

Subject Characteristics or Selection Bias

The study focused on the relationships among perceived stress, BP, HRV, and meditation practice. When these variables of interest are correlated, there may be other characteristics that could explain any relationships that are found. For example, those who volunteer to participate in a study could systematically introduce extraneous variables into the study. This threat was minimized in two ways. First, variations in demographic characteristics were controlled using partial correlation analysis. Secondly, all eligible meditators who volunteered and who provided informed consent were enrolled in the study. However, it is possible that there were extraneous variables influencing the study outcomes.

Location

A location threat might be possible when instruments are administered to participants at different sites. The researcher controlled location threat by using the same room either on the second floor at the Ekoji Buddhist Sangha of Richmond or the Dharma room at Still Water Zen Center, depending on the site used by participants for meditation practice. The researcher also used consistent procedures for each participant, regardless of location, as described previously in the procedure section.

Instrumentation

Instrumentation threat could occur if either physiological measuring devices or study questionnaires were changed in some way over the course of the study. In terms of the validity of the measurement from the equipment used in the study, calibration and maintenance procedures were carried out in accordance with the manufacturer's recommendations. The researcher calibrated the Omron model HEM-705CP automatic sphygmomanometer to be used in the study once a year at the General Clinical Research Center (GCRC) of Virginia Commonwealth University Medical Center. The systolic and diastolic BP were different from the standard mercury sphygmomanometer ± 4 mmHg. The Log-a-Rhythm® Model 100 was maintained according to the manufacturer’s specification (Appendix E) to ensure accuracy of measurement. Additionally, all questionnaires were administered consistently, and without modification across the study.

Correlations could not be obtained unless the researcher had scores for each person on variables being analyzed. Thus, the researcher reviewed all questionnaires while the participant was meditating to assure that each question was filled out completely. Any missing information was obtained from the participant following the final BP measurement. Additionally, successfully obtaining HRV depends on many factors, such as correct placement of electrodes, functioning batteries in a Signal Acquisition Unit of a

Log-a-Rhythm, and analyzing heart data using the Log-a-Rhythm® Heart Rate Analysis Software. Thus, the researcher was supervised by an experienced user of this specific HRV monitor until she demonstrated consistent competence using the equipment. She maintained her competence through ongoing practice. In order to prevent missing HRV data, she changed the batteries in a Signal Acquisition Unit of a Log-a-Rhythm before recording heart data for each participant, followed the instruction manual, and checked all connections during heart data recording and during analysis of heart rate according to the procedures in the manufacturer's manual.

Testing

Testing threat refers to the influence of completing one questionnaire on subsequent questionnaires. A meditation form, a perceived stress scale and questionnaire, and a demographic form were completed at one time point only by all participants, prior to collection of physiological data. Each form addressed different topics and responses to one were not anticipated to affect other responses. However, the study was not designed to assess any effects of administrating multiple questionnaires. The questionnaires were administered in the same order to all participants and if there was a testing effect, it would have been consistent across all participants.

Data Management

All heart rate data were exported from the Log-a-Rhythm software program to the JMP IN Version 5.1 for Windows statistical software program. Then, two main spectral components, LF power and HF power were calculated from hertz (Hz) to normalized units (n.u.) by dividing the absolute power of each component by the total power within a range of 0.04 and 0.5 Hz and multiplying by 100 (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrotophysiology, 1996). Information from questionnaires, and the systolic and diastolic BP values were written on the data form and manually entered into JMP database. The researcher double-checked all entered data with the original data to ensure accuracy. Finally, the JMP program calculated a total PSS score and average systolic and diastolic BP before and after meditation.

Data Analysis

The JMP IN Version 5.1 for Windows statistical software program was used for data analysis. Statistical procedures appropriate the level of data were used. The level of significance for all statistical tests was set at 0.05. Descriptive statistics, such as frequency, means, standard deviations, ranges, and 95% confidence intervals (CI), were used to summarize the sample variables. Differences between average systolic BP pre- and post-meditation were compared by using paired-*t* tests, as were differences between average diastolic BP pre- and post-meditation. Then, multivariate correlations were used for preliminary analysis in order to examine the overall relationships among variables of interest, including meditation practice (length, frequency, and session duration), perceived current stress, perceived stress score, systolic BP, diastolic BP, and LF power, and HF power of HRV. Pearson product moment correlation coefficients, and one-way analysis of variance (ANOVA), were also used for preliminary analyses. Multivariate multiple regression and analysis of covariance (ANCOVA) were used to predict dependent variables by independent variables in order to test the two research hypotheses, (1) perceived stress has a positive correlation with BP and LF power, and an inverse correlation with HF power in meditators; and (2) meditation practice has a negative correlation with perceived stress, BP, and LF power, and a positive correlation with HF power in meditators, Age, gender, and race were tested as possible confounding variables using multivariate analysis of variance (MANOVA). The outcomes of all analyses will be described in chapter 4.

Summary

This chapter provided information regarding the research design and methods used in this study. A cross-sectional descriptive-correlational design was used to examine the relationships among perceived stress, BP, and HRV in meditators. The sampling method and subject recruitment approaches, data collection procedures, data analysis plan and human subjects protections were described. The findings of the study are presented in Chapter 4.

Chapter 4

Results

The purpose of this study was to examine the relationships among perceived stress, blood pressure (BP), heart rate variability (HRV), and meditation practice in meditators. This chapter includes information regarding the demographic characteristics of the sample and the outcomes of the statistical tests related to the two research hypotheses: (1) perceived stress has a positive correlation with BP and low frequency (LF) power, and an inverse correlation with high frequency (HF) power in meditators; and (2) meditation practice has a negative correlation with perceived stress, BP, and LF power, and a positive correlation with HF power in meditators.

Descriptive Statistics

Demographic Characteristics

Participants in this study included 71 meditators who had practiced meditation at either Ekoji Buddhist Sangha of Richmond or Still Water Zen Center. The average age of participants was 43.75 years (SD = 12.22, range = 21−80, *95% CI* = [40.85, 46.64]). Categorical demographic descriptors including gender, race, religion, education, and regular use of medication are presented in Table 8. Of the 42% who reported using medications, the following were reported: birth control pills, antidepressants,

Table 8

Demographic Characteristics and Type of Meditation Practice of Sample (N = 71)

Variables	*n*	%
Gender:		
Male	34	48
Female	37	52
Race:		
Caucasian/White	67	94
African American/Black	2	3
American-Asian	2	3
Religion:		
Buddhism	54	76
Christian	2	3
Other (None, Not consider, No religious, Agnostic)	11	15
Other (Mixed philosophy, Multidenominationalism, Taoist, Unitarian universalism)	4	6
Education:		
High school graduate	1	1
Some college	4	6
College graduate	36	51
Graduate degree	30	42
Regular use of any medicine:		
Yes	30	42
No	41	58
Current form of meditation practice:		
Soto zen	32	45
Vipassana	21	30
Pure land	3	4
Tibetan karma kagyu	3	4
Korean/rinzai zen	7	10
Other (zen, bonpo, guided imagery, yoga)	5	7
Ever practiced other forms of meditation		
Yes	41	58
No	30	42

antipsychotics, antihistamines, muscle relaxants, osteoporosis medicine, pain medicine, estrogen and thyroid supplements, and antiviral, antilipid or antiseizure drugs.

Meditation Practice

As shown in Table 8, most participants practiced soto zen or vipassana meditation (45% and 30%, respectively). Fifty eight percent had also practiced forms of meditation different from their current form. Those who did change forms of meditation practice reported that they needed to find out which techniques were better for them. There was variability in the length of total meditation practice (see Table 9). The average length of total meditation practice was 103.66 months (SD = 113.07) as noted in Table 10. Their current practice techniques had an average of 56.69 months (SD = 68.62). Participants practiced meditation an average of 4.28 days a week (SD = 1.84) and 1.18 times a day (SD = 0.57) with mean session duration of 33.52 minutes (SD = 14.45).

Table 9

Categories of Length of Total Meditation Practice (N = 71)

Categories of Length of Total Meditation Practice	*n*	%
≤ 12 months	8	11.27
13−36 months	18	25.35
37−60 months	10	14.08
61−120 months	17	23.94
> 120 months	18	25.36

Table 10

Descriptive Statistics: Meditation Practice, Perceived Stress, Blood Pressure, and Heart Rate Variability (N = 71)

Variables	*M*	*SD*	Range	*95% CI*
Length of total meditation practice (months)	103.66	113.07	4.00-480.00	[76.90, 130.43]
Current meditation practice:				
Length of current practice (months)	56.69	68.62	1.00−360.00	[40.45, 72.93]
Frequency per week (days)	4.28	1.84	1.00−7.00	[3.85, 4.72]
Frequency per day (times)	1.18	0.57	1.00−5.00	[1.05, 1.32]
Session duration per time (minutes)	33.52	14.45	10.00−70.00	[30.10, 36.94]
Perceived stress:				
Current stress	3.49	1.54	1.00−8.00	[3.13, 3.86]
Perceived stress score (past month)	15.20	5.38	4.00−30.00	[13.92, 16.47]
Blood pressure (pre-meditation):				
Systolic BP (mmHg)	123.85	8.99	98.50−139.50	[121.72, 125.97]
Diastolic BP (mmHg)	79.14	6.35	63.50−91.00	[77.64, 80.64]
Blood pressure (post-meditation):				
Systolic BP (mmHg)	119.62	8.79	99.00−139.00	[117.54, 121.70]
Diastolic BP (mmHg)	79.47	7.46	61.00−98.00	[77.71, 81.24]
Heart rate variability (during meditation)				
LF power (n.u.)	48.17	23.50	1.11−91.42	[42.61, 53.73]
HF power (n.u.)	28.43	20.55	0.17−70.82	[23.57, 33.29]

Note. BP = Blood pressure, mmHg = Millimeters of standard mercury, LF = Low frequency, HF = High frequency, and n.u. = Normalized unit.

Perceived Stress

In this study perceived stress was assessed by a visual analogue scale for perceived current stress as well as the Perceived Stress Scale. The average of perceived current stress was 3.49 (*SD* = 1.54, range = 1−8), with 89% reporting low levels of current stress (scores of 1 to 5). Similarly, the mean PSS score was 15.20 (*SD* = 5.38, range = 4−30) indicating a low level of stress among participants (see Table 10) when compared with the highest possible perceived stress score of 40. Though not systematically collected, informally reported sources of stress reported included work, family and friends.

Physiological Measures

In this study, the autonomic nervous system was assessed through BP and HRV. As summarized in Table 10, mean systolic BP was slightly higher than what is currently viewed as optimal systolic pressure (120 mmHg), while mean diastolic BP was within what is considered the range of normal (80 mmHg) (Chobanian et al., 2003). Before meditation, 62% of participants had systolic BP greater than 120 mmHg; however, after meditation most participants had systolic BP less than 120 mmHg (see Table 11). Interestingly, the number of participants having diastolic BP less than 80 mmHg after meditation was smaller than before meditation (see Table 11).

When comparing number of participants' changes in systolic BP before and after meditation, most participants were in the group of systolic BP greater than 120 mmHg at pre-and post-meditation. About 4% of participants who had normal systolic BP at pre-meditation had an increase in systolic BP greater than 120 mmHg at post-meditation (see Figure 6). Similarly in comparing changes in diastolic BP, most participants were in the group of normal diastolic BP at pre- and post-meditation. About 8% of participants who had normal diastolic BP prior to meditation had an increase in diastolic BP greater than 80 mmHg at post-meditation (See Figure 7).

Table 11

Comparison of Blood Pressure Before and After Meditation (N = 71)

Variables	Pre-meditation		Post-meditation	
	n	%	*n*	%
Systolic BP ≤ 120 mmHg	27	38.03	39	54.93
Systolic BP > 120 mmHg	44	61.97	32	45.07
Diastolic BP ≤ 80 mmHg	42	59.15	39	54.93
Diastolic BP > 80 mmHg	29	40.85	32	45.07

Note. BP = Blood pressure, mmHg = Millimeters of standard mercury.

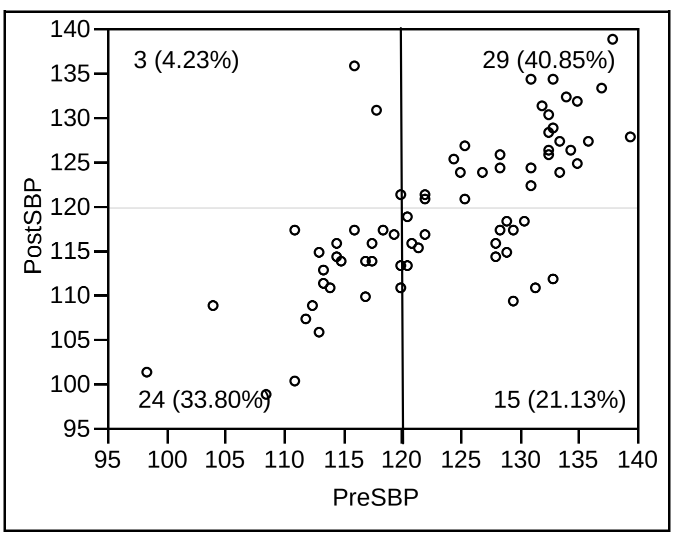

Figure 6. Comparison of Number of Participants' Changes in Systolic Blood Pressure

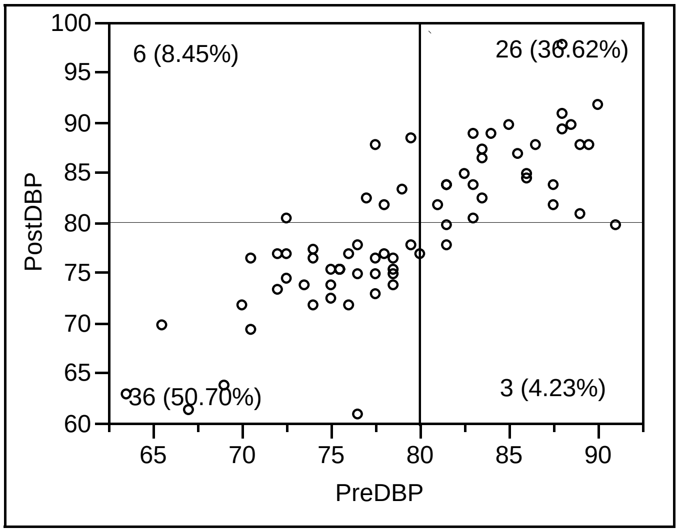

Figure 7. Comparison of Number of Participants' Changes in Diastolic Blood Pressure

The mean LF power, expressed in normalized units and representing both sympathetic and parasympathetic activities, was 48.17% of the total power spectrum (*SD* = 23.50). The mean HF power, also expressed in normalized units but representing primarily parasympathetic activity, was 28.43% of the total power spectrum (*SD* = 20.55). These results are seen in Table 10. The LF power and HF power measures were also considered to be within the normal range according to norms established by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrotophysiology (1996) (see Table 1, p. 17 of this document).

Preliminary Analyses

Changes in Blood Pressure after Meditation Practice

A paired *t*-test was performed to compare mean systolic BP before and after meditation. Similarly, mean diastolic BP before and after meditation were compared. The findings are displayed in Table 12. Mean systolic BP after meditation significantly decreased when compared to the pre-meditation measurement; however, there was no statistically significant change in diastolic BP. Therefore, meditation practice appeared to lower only systolic BP in this group of participants.

Table 12

Paired t-tests of Blood Pressure Differences Before and After Meditation (N = 71)

Variables	Pre-meditation		Post-meditation		Difference		t
	M	SD	M	SD	M	SD	
Systolic BP	123.85	8.99	119.62	8.78	–4.23	6.71	5.31[a]
Diastolic BP	79.14	6.35	79.47	7.46	.33	4.42	.63

Note. BP = Blood pressure. [a] $p < .0001$.

Relationships among Stress, Blood Pressure, Heart Rate Variability, and Meditation Practice in Meditators

Multivariate correlations were used to assess the overall relationships among the study measures (see Table 13). Length of total meditation practice was inversely correlated with perceived current stress ($r = -.25$, $p = .04$), indicating that the longer the participants practiced meditation, the lower the levels of perceived current stress. Other significant correlations were between length of total meditation practice and frequency of meditation practice per week ($r = .43$, $p < .001$) and between frequency of meditation practice per week and frequency of meditation practice per day ($r = .25$, $p < .05$). As expected, there was a significant positive relationship between post-meditation systolic and diastolic BP ($r = .60$, $p < .0001$), while LF power had an inverse significant correlation with HF power ($r = -.41$, $p < .001$).

Statistical Testing of Research Hypotheses

The purposes of this study were to evaluate the relationships between perceived stress and reactivity of the ANS as observed by BP and HRV in experienced meditators, as well as the relationships between meditation practice and perceived stress and reactivity of the ANS as assessed by BP and HRV, also in meditators. Pearson product moment correlation coefficients and one-way analysis of variance (ANOVA) were used for preliminary analyses. Then, multivariate multiple regression and analysis of covariance (ANCOVA) were used to test the two research hypotheses: (1) perceived stress has a positive correlation with BP and LF power, and an inverse correlation with HF power in meditators; and (2) meditation practice has a negative correlation with perceived stress,

Table 13

Correlation Matrix among Meditation Practice, Perceived Current Stress, Perceived Stress Score, Post-meditation Blood Pressure, and Heart Rate Variability (N=71)

Variables	1	2	3	4	5	6	7	8	9
1. Length of practice	1								
2. Frequency of practice (days/wk)	.43[b]	1							
3. Frequency of practice (times/day)	.18	.25[a]	1						
4. Duration of practice	.02	–.07	.08	1					
5. Current stress	–.25[a]	–.08	–.04	.15	1				
6. PSS	–.11	–.19	.04	.04	.21	1			
7. Post systolic BP	–.08	–.07	.00	.06	–.02	–.11	1		
8. Post diastolic BP	–.06	–.16	–.04	.08	–.11	–.11	.60[c]	1	
9. LF power (n.u.)	–.10	–.09	.04	–.11	–.12	–.21	.19	.08	1
10. HF power (n.u.)	.00	–.14	.02	.17	.00	.18	.02	.00	–.41[b]

Note. PSS = Perceived stress score, BP = Blood pressure, LF = Low frequency, HF = High frequency, and n.u. = Normalized units. [a] $p < .05$, [b] $p < .001$, [c] $p < .0001$

BP, and LF power, and a positive correlation with HF power in meditators.

Relationships among Perceived Stress, Blood Pressure and Heart Rate Variability

To answer the first research hypothesis, "perceived stress has a positive correlation with BP and LF power, and an inverse correlation with HF power in meditators", a preliminary analysis was performed using bivariate analysis. Then, multivariate multiple regressions were used to examine the effect of perceived stress on BP and HRV.

Effects of perceived stress on blood pressure. Figure 8 displays scatterplots of post-meditation BP by scores for perceived current stress and PSS. There were no statistically significant relationships among these study measures. As shown in Table 14, perceived current stress was not significantly correlated with either post-meditation systolic BP ($r = -.02$, $df = 69$, $p = .87$) or post-meditation diastolic BP ($r = -.11$, $p = .37$). Similarly, PSS was not significantly correlated with post-meditation systolic BP ($r = -.11$, $p = .35$) or post-meditation diastolic BP ($r = -.11$, $p = .37$) as noted in Table 15. These findings indicated that there was no evidence of relationships among perceived current stress or PSS and the ANS indicators assessed through BP.

Effects of perceived stress on heart rate variability. Figure 8 also shows scatterplots of HRV by perceived current stress and PSS. Perceived current stress was not significantly correlated with either LF power ($r = -.12$, $p = .34$) or HF power ($r = .00$, $p = .99$) (see Table 14). Similarly, PSS was not significantly correlated with either LF power ($r = -.21$, $p = .07$) or HF power ($r = .18$, $p = .14$) (see Table 15). These findings indicated that there was no evidence of relationships between perceived current stress or PSS and the ANS assessed through HRV.

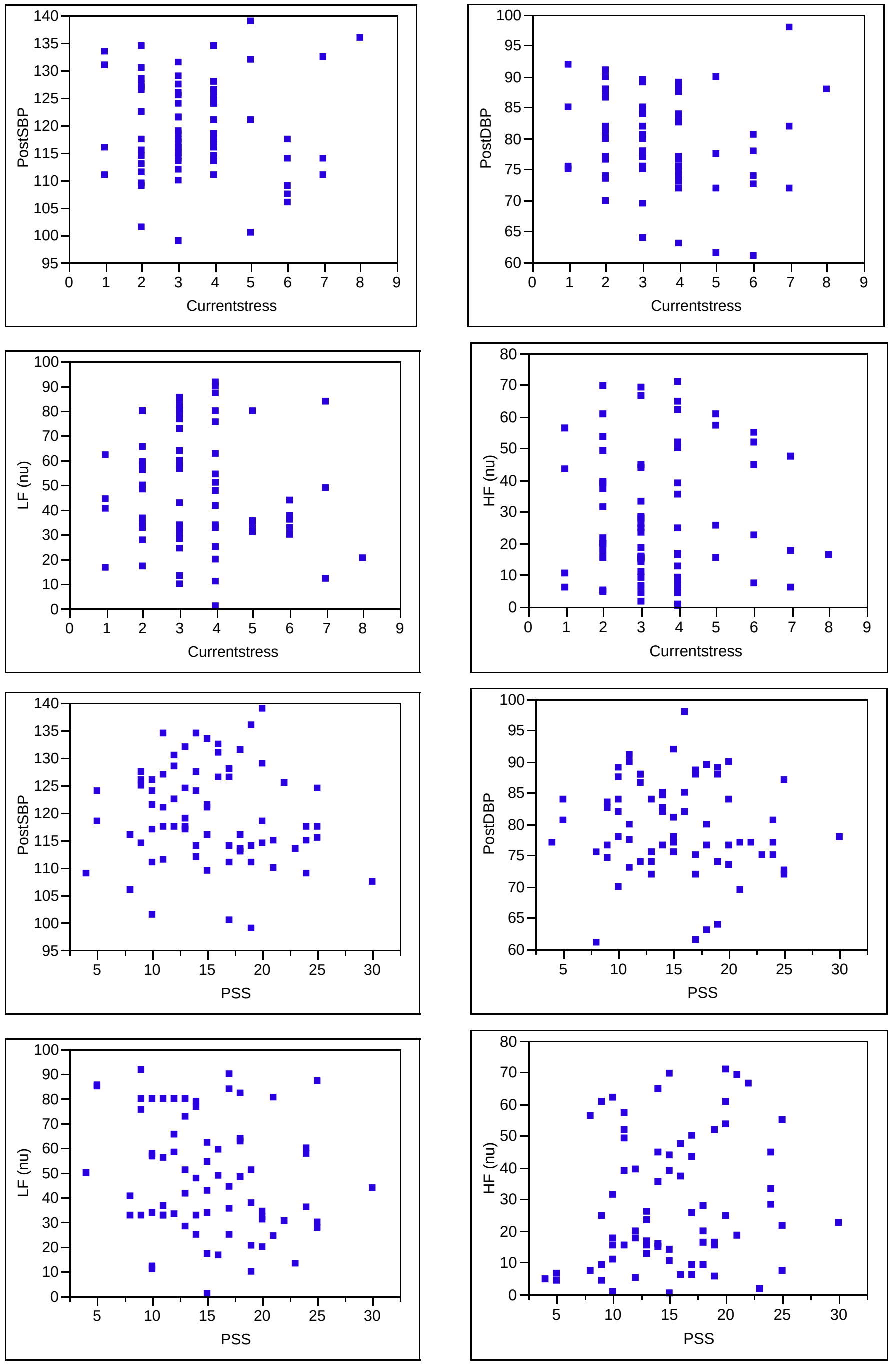

Figure 8. Bivariate analyses of post-meditation blood pressure and heart rate variability by perceived current stress and perceived stress score.

Table 14

Parameter Estimates of Post-meditation Blood Pressure and Heart Rate Variability by Perceived Current Stress Using Bivariate Analysis (N = 71)

Term	Estimate	*SE*	*t*	*p*	*Std Beta*
Post-meditation Systolic BP					
Intercept	120	2.62			
Perceived current stress	–.11	.69	–.16	.87	–.02
Post-meditation Diastolic BP					
Intercept	81.29	2.21			
Perceived current stress	–.52	.58	–.90	.37	–.11
LF power					
Intercept	54.37	6.96			
Perceived current stress	–1.77	1.83	–.97	.34	–.12
HF power					
Intercept	28.52	6.13			
Perceived current stress	–.03	1.61	–.02	.99	.00

Note. BP = Blood pressure, LF = Low frequency, and HF = High frequency.

Table 15

Parameter Estimates of Post-meditation Blood Pressure and Heart Rate Variability by Perceived Stress Score Using Bivariate Analysis (N = 71)

Term	Estimate	*SE*	*t*	*p*	*Std Beta*
Post-meditation Systolic BP					
Intercept	122.44	3.15			
PSS	–.19	.19	–.95	.35	–.11
Post-meditation Diastolic BP					
Intercept	81.76	2.67			
PSS	–.15	.17	–.91	.37	–.11
LF power					
Intercept	62.34	8.27			
PSS	–.93	.51	–1.82	.07	–.21
HF power					
Intercept	18.12	7.29			
PSS	0.68	.45	1.50	.14	.18

Note. PSS = Perceived stress score, BP = Blood pressure, LF = Low frequency, and HF = High frequency.

Effects of perceived stress on blood pressure and heart rate variability. Multivariate multiple regression models were used to examine relationships among perceived stress, BP, and HRV (see Table 16). Multivariate analysis of variance (MANOVA) was first used to examine the overall relationships among the study measures. However, MANOVA failed to show overall significant relationships (F [8, 130] = .79, p = .62). Neither perceived current stress nor PSS showed significant relationships with the dependent variables of post-meditation systolic BP, post-meditation diastolic BP, LF power or HF power. In addition, findings from ANOVA indicated that neither perceived current stress nor PSS were significant predictors of post-meditation systolic BP, post-meditation diastolic BP, LF power, or HF power. Thus, the null hypothesis "perceived stress has no correlation with systolic BP, diastolic BP, LF power, and HF power in meditators" could not be rejected. There was no evidence of relationships among perceived stress and the ANS assessed through BP and HRV in experienced meditators.

Relationships among Perceived Stress, Blood Pressure, Heart Rate Variability and Meditation Practice

To test the last research hypothesis, "meditation practice has a negative correlation with perceived stress, BP, and LF power, and a positive correlation with HF power in meditators", a preliminary analysis was performed using multivariate correlations and ANOVA. ANCOVA was then used to predict the six outcome variables.

Table 16

Multivariate Multiple Regression of Post-meditation Blood Pressure, and Heart Rate Variability on Perceived Current Stress and Perceived Stress Score (N = 71)

	MANOVA		ANOVA							
			Post SBP		Post DBP		LF power		HF power	
Variable	*df*	*F*	*df*	*F*	*df*	*F*	*df*	*F*	*df*	*F*
Whole model	8, 130	.79	2, 68	.45	2, 68	.67	2, 68	1.82	2, 68	1.17
Perceived current stress	4, 65	.44	1, 68	.00	1, 68	.52	1, 68	.38	1, 68	.12
PSS	4, 65	1.02	1, 68	.87	1, 68	.53	1, 68	2.67	1, 68	2.33

Note. PSS = Perceived stress score, SBP = Systolic blood pressure, DBP = Diastolic blood pressure, LF = Low frequency, and HF = High frequency. MANOVA = Multivariate analysis of variance. ANOVA = Analysis of Variance. Multivariate *F* ratios are Wilk's approximation of the *Fs*. Results were not statistically significant (all $p > .1$)

Effects of meditation practice on perceived stress, blood pressure, and heart rate variability. As shown in Table 13, no statistically significant correlations were found (all $p > .1$), except between perceived current stress and length of total meditation practice. Length of total meditation practice was negatively correlated with perceived current stress ($r = -.25$, $p < .05$). Thus, prolonged meditation practice was associated with a lower level of perceived current stress.

Effects of types of meditation practice on perceived stress, blood pressure, and heart rate variability. To assess the possible effects of types of meditation practice, a one-way ANOVA compared six types of meditation practice. The outcome variables were perceived current stress, PSS, post-meditation systolic BP, post-meditation diastolic BP, LF power, and HF power. There were no statistically significant differences in perceived current stress (F (5, 65) = 1.20, p = .32), PSS (F (5, 65) = .46, p = .80), post-meditation systolic BP (F (5, 65) = .40, p = .85), post-meditation diastolic BP (F (5, 65) = 1.15, p = .34), LF power (F (5, 65) = 1.06, p = .39), or HF power (F (5, 65) = .76, p = .59), as shown in Table 17.

Predicting Perceived Stress, Blood Pressure, and Heart Rate Variability by Meditation Practice

ANCOVA, a combination of multiple regression and ANOVA methods (Polit, 1996), was used to predict the six outcome variables: perceived current stress, PSS, post-meditation systolic BP, post-meditation diastolic BP, LF power, and HF power by meditation practice. Results of tests of the research hypothesis, “meditation practice has a negative correlation with perceived stress, BP, and LF power, and a positive correlation with HF power in meditators” follow.

Table 17

Means for One way ANOVA of Perceived Stress, Post-meditation Blood Pressure, and Heart Rate Variability by Type of Meditation Practice (N = 71)

Type	*n*	*M*	*SE*	Lower *95% CI*	Upper *95% CI*
Perceived current stress					
Soto zen	32	3.65	.27	3.12	4.19
Vipassana	21	3.67	.33	3.00	4.33
Pure land	3	4.33	.88	2.57	6.09
Tibetan	3	2.33	.88	.57	4.09
Korean/rinzai zen	7	2.57	.58	1.41	3.72
Other (zen, bonpo, guided imagery, yoga)	5	3.20	.68	1.83	4.56
PSS					
Soto zen	32	14.84	.97	12.91	16.78
Vipassana	21	16.10	1.20	13.7	18.49
Pure land	3	17.33	3.17	11.01	23.66
Tibetan	3	16.67	3.17	10.34	22.99
Korean/rinzai zen	7	13.57	2.07	9.43	18.70
Other (zen, bonpo, guided imagery, yoga)	5	13.80	2.45	8.90	17.71
Post-meditation systolic BP					
Soto zen	32	119.98	1.59	116.81	123.16
Vipassana	21	120.00	1.96	116.09	123.91
Pure land	3	114.67	5.19	104.31	125.02
Tibetan	3	123.67	5.19	113.31	134.02
Korean/rinzai zen	7	118.79	3.39	112.01	125.57
Other (zen, bonpo, guided imagery, yoga)	5	117.40	4.02	109.38	125.42
Post-meditation diastolic BP					
Soto zen	32	79.34	1.31	76.72	81.96
Vipassana	21	80.05	1.62	76.81	83.28
Pure land	3	73.83	4.28	65.28	82.39
Tibetan	3	84.50	3.31	75.95	93.05
Korean/rinzai zen	7	81.79	2.80	76.19	87.39
Other (zen, bonpo, guided imagery, yoga)	5	75.00	3.32	68.37	81.63

Table 17 *(continued)*

Type	*n*	*M*	*SE*	Lower *95% CI*	Upper *95% CI*
		LF power			
Soto zen	32	44.28	4.14	36.00	52.55
Vipassana	21	49.22	5.12	39.01	59.44
Pure land	3	59.26	13.54	32.23	86.29
Tibetan	3	72.99	13.54	45.96	100.02
Korean/rinzai zen	7	51.14	8.86	33.45	68.84
Other (zen, bonpo, guided imagery, yoga)	5	42.96	10.48	22.02	63.90
		HF power			
Soto zen	32	26.64	3.67	19.32	33.96
Vipassana	21	30.69	4.52	21.65	39.72
Pure land	3	25.41	11.97	1.50	49.31
Tibetan	3	14.51	11.97	-9.40	38.41
Korean/rinzai zen	7	28.06	7.84	12.41	43.71
Other (zen, bonpo, guided imagery, yoga)	5	41.10	9.27	22.58	59.61

Note. ANOVA = Analysis of Variance. PSS = Perceived stress score, BP = Blood pressure, LF = Low frequency, and HF = High frequency. Results were not statistically significant (all $p > .1$).

Predicting perceived stress by meditation practice. Table 18 depicts the ANCOVA results for predicting perceived current stress by the form of meditation practice. ANCOVA failed to show overall significant predictors of perceived current stress (F [9, 61] = 1.33, $p = .24$). Length of total meditation practice was the only significant predictor of perceived current stress (F [1, 61] = 4.17, $p = .04$).

There were no statistically significant predictors of PSS by the meditation practice variables (F [9, 61] = .62, $p = .78$). None of the main effects of meditation practice were significant predictors of PSS (all $p > .1$) (see Table 19).

Table 18

ANCOVA Results for Predicting Perceived Current Stress (N = 71)

	Perceived Current Stress			
Variable	*df*	*MS*	*F*	*p*
Whole model	9	3.03	1.33	.24
Length of total practice	1	9.46	4.17	.04
Type of practice	5	2.48	1.09	.37
Frequency of practice (days/wk)	1	.02	.01	.92
Frequency of practice (times/day)	1	.00	.00	.98
Session duration of practice	1	2.19	.97	.33
Error	61	2.27		
Total	70			

Note. ANCOVA = Analysis of covariance.

Table 19

ANCOVA Results for Predicting PSS (N = 71)

	PSS			
Variable	*df*	*MS*	*F*	*p*
Whole model	9	18.91	.62	.78
Length of total practice	1	1.12	.04	.85
Type of practice	5	14.2	.47	.80
Frequency of practice (days/wk)	1	71.03	2.33	.13
Frequency of practice (times/day)	1	16.67	.55	.46
Session duration of practice	1	.07	.00	.96
Error	61	30.44		
Total	70			

Note. ANCOVA = Analysis of covariance. PSS = Perceived stress score.

Predicting blood pressure by meditation practice. The results of the ANCOVA also showed no significant overall effect of the meditation practice session on post-meditation systolic BP (F ([9, 61] = .27, p = .98). There were no significant main effects of meditation practice for systolic BP (all p > .6, Table 20). In addition, ANCOVA failed to show any overall effect of the meditation practice on post-meditation diastolic BP (F [9, 61] = .79,

p = .63), nor any significant main effects for post-meditation diastolic BP (all $p > .2$, Table 21).

Predicting heart rate variability by meditation practice. As shown in Table 22, among experienced meditators in this study, meditation practice had no overall significant effects on LF power (F [9, 61] = .65, p = .75). There were no significant main effects for LF power (all $p > .5$). Similar findings were noted for the effects of meditation on HF power (Table 23).

Lastly, the effects of age, gender and race were addressed through statistical analyses. MANOVA indicated that only gender was potentially related to any of the six outcome variables including perceived current stress, PSS, post-meditation systolic BP, post-meditation diastolic BP, LF power, and HF power. When gender was added as an additional predictor in the analyses of the effect of meditation practice on perceived stress, BP, and HRV, none of the results changed (see Table 16). Thus, the null hypothesis "meditation practice has no correlation with perceived stress, BP and HRV in meditators" could not be rejected. There was no evidence of relationships among meditation practice, perceived stress and the ANS assessed through BP and HRV in meditators, with the exception of an inverse relationship between total length of meditation practice and perceived current stress.

In summary, neither of the study hypotheses was supported by the data from the participants in this study. However, perceived current stress had a significant negative correlation with length of total meditation practice. There was the additional finding that systolic BP after meditation was significantly lower than before meditation.

Table 20

ANCOVA Results for Predicting Post-meditation Systolic BP (N = 71)

	Post-meditation Systolic BP			
Variable	*df*	*MS*	*F*	*p*
Whole model	9	22.85	.27	.98
Length of total practice	1	20.01	.23	.63
Type of practice	5	29.15	.34	.89
Frequency of practice (days/wk)	1	3.35	.04	.84
Frequency of practice (times/day)	1	2.01	.02	.88
Session duration of practice	1	7.46	.09	.77
Error	61	85.21		
Total	70			

Note. ANCOVA = Analysis of covariance. BP = Blood pressure.

Table 21

ANCOVA Results for Predicting Post-meditation Diastolic BP (N = 71)

	Post-meditation Diastolic BP			
Variable	*df*	*MS*	*F*	*p*
Whole model	9	45.29	.79	.63
Length of total practice	1	2.81	.05	.83
Type of practice	5	58.75	1.03	.41
Frequency of practice (days/wk)	1	67.87	1.19	.28
Frequency of practice (times/day)	1	1.58	.03	.87
Session duration of practice	1	3.32	.06	.81
Error	61	57.16		
Total	70			

Note. ANCOVA = Analysis of covariance. BP = Blood pressure.

Table 22

ANCOVA Results for Predicting LF Power of HRV (N = 71)

	LF power			
Variable	*df*	*MS*	*F*	*p*
Whole model	9	376.56	.65	.75
Length of total practice	1	84.56	.15	.70
Type of practice	5	443.29	.77	.58
Frequency of practice (days/wk)	1	40.02	.07	.79
Frequency of practice (times/day)	1	133.43	.23	.63
Session duration of practice	1	231.39	.40	.53
Error	61	578.06		
Total	70			

Note. ANCOVA = Analysis of covariance. LF = Low frequency.

HRV = Heart rate variability

Table 23

ANCOVA Results for Predicting HF Power of HRV (N = 71)

	HF power			
Variable	*df*	*MS*	*F*	*p*
Whole model	9	395.75	.93	.51
Length of total practice	1	34.30	.08	.78
Type of practice	5	419.56	.98	.43
Frequency of practice (days/wk)	1	1103.04	2.59	.11
Frequency of practice (times/day)	1	2.46	.01	.94
Session duration of practice	1	401.77	.94	.34
Error	61	426.22		
Total	70			

Note. ANCOVA = Analysis of covariance. HF = High frequency.

HRV = Heart rate variability

Summary

The findings of the study were described in this chapter. Demographic characteristics of the sample as well as descriptive analysis of the variables of interest (perceived stress, BP, HRV, and meditation practice) were presented. Statistical tests used to analyze data were described, including preliminary analyses among variables of interest using multivariate correlations, paired *t*-tests, Pearson product moment correlation coefficients, and ANOVA. Then, the two research hypotheses were tested using multivariate multiple regression and ANCOVA. The results revealed that there were no statistically significant relationships among perceived stress, BP, and HRV in meditators. In addition, meditation practice had no statistically discernable effects on perceived stress, BP, and HRV in study participants, with the exception of an inverse relationship between total length of meditation practice and perceived current stress. Discussion, conclusions, implications, and recommendations for future research and knowledge development are provided in Chapter 5.

Chapter 5

Discussion

This final chapter includes discussion, conclusions, and implications related to the study outcomes. The strengths and limitations of the study are also provided. Finally, recommendations for future research, practice and theory development are offered.

Discussion

The sample size of this study exceeded that of most previous studies conducted (Astin, 1997; Barnes et al., 1999; Barnes et al., 2001; Chang, et al., 2004; Cysarz & Bussing, 2005; Furlan et al., 2000; Goleman & Schawartz, 1976; Hjortskov et al., 2004; Matthews et al., 2001; Matzner, 2003; Murata et al., 2004; Peng et al., 1999; Peng et al., 2004; Robinson et al., 2003; Sloan et al., 1996; Sudsuang et al., 1990; Takahashi et al., 2005; Waelde et al., 2004), and the study design included a power analysis to determine the necessary sample size to achieve a power of 80%. Most other previous studies using meditators had similar demographic profiles of participants in terms of age, gender, and race (Barnes et al., 1999; Chang et al., 2004; Peng et al., 2004; Robinson et al., 2003; Solberg et al., 2004; Wallace et al., 1983). This study reported demographic data in more detail than did most other studies which were reviewed (Barnes et al., 1999; Cysarz & Bussing, 2005; Goleman & Schawartz, 1976; Matzner, 2003; Peng et al., 1999; Peng et al., 2004; Solberg et al., 2004; Wallace et al., 1983).

Current forms of meditation practice used by participants in other studies included both those used by participants in this study and also Chinese chi (qigong) meditation (Peng et al., 1999), kundalini yoga meditation (Matzner, 2003; Peng et al., 1999; Peng et al., 2004), transcendental meditation (Barnes et al., 1999; Barnes et al., 2001; Barnes et al., 2004; Goleman & Schwartz, 1976; Wallace et al., 1983), dhammakaya meditation (Sudsuang et al., 1990), and mindfulness meditation (Astin, 1997; Chang et al., 2004; Robinson et al., 2003; Shapiro et al., 1998). Though forms of meditation practice have some different features, all forms use concentration, mindfulness, or both. Thus, there is similarity between the general features of meditation used by participants in other studies and those reported by participants in this study.

All participants in this study were meditators who regularly practiced meditation with a mean length of total meditation practice of 103.66 months. Participants also revealed that they practiced meditation an average of 4.28 days a week and 1.18 times a day with mean session duration of 33.52 minutes. However, meditation practice of this sample had some variability, ranging from novice to experienced meditators. Most participants (63%) were experienced meditators (more than 36 months) and about 11% of the sample were novice meditators who practiced meditation 12 months or less (see Table 9, p. 86). In comparison to previous studies using only meditators, this study sample was most like that of Wallace et al. (1983), which included those who had meditated from 1 to 180 months, for a mean of 79.5 months. Participants in the Peng et al. study (2004) had 3-15 years of experience and practiced up to five or more times/week.

Other studies reviewed also used both meditators and non-meditators. For example, Goleman and Schwartz (1976) used meditators with more than two years of experience with meditation compared with non-meditators. Peng et al. (1999) reported that most chi meditators were novices, while all kundalini yoga participants were advanced meditators. Two of nine participants were experienced meditators in the Cysarz and Bussing (2005) study. Unfortunately, these researchers did not report the length and frequency of meditation practice. Thus, the quantity of meditation practice in previous studies cannot be compared with this study.

There were inconsistent findings in the literature regarding the relationship between stress and heart rate variability. Not surprisingly, therefore, findings in this study, that there was no correlation between perceived stress and low frequency (LF) power, were similar to some previous studies (Kang et al., 2004; Hjortskov et al., 2004; Papousek et al., 2002) and different from two studies (Furlan et al., 2000; Sloan et al., 1996). Most studies reviewed found that there was an inverse but significant relationship between perceived stress and high frequency (HF) power (Hjortskov et al., 2004; Papousek et al., 2002; Sloan et al., 1996), which differs from this study, in which there was no relationship between perceived stress and HF power. However, the results are congruent with Kang et al.'s study (2004) of non-meditators, in which there were no significant correlations among perceived stress and heart rate variability (HRV).

Participants' systolic and diastolic blood pressure (BP) in this study were similar to mean systolic BP (122 mmHg) and mean diastolic BP (79 mmHg) for the white population between 35 and 44 years of age (U.S. Department of Health and Human Services, 2003).

Decreased systolic BP after meditation noted in this study is congruent with some studies employing meditators (Barnes et al., 1999; Barnes et al., 2001; Barnes et al., 2004; Sudsuang et al., 1990; Wallace et al., 1983). Unchanged diastolic BP after meditation in this study is similar to Solberg et al.'s study (2004) and Barnes et al.'s study (1999), but differs from three studies (Barnes et al., 2001; Barnes et al., 2004; Sudsuang et al., 1990), that found participants had a decrease in diastolic BP after meditation when compared to before meditation. A possible reason for unchanged diastolic BP in this study is that participants may have already achieved a low diastolic BP and there may be physiological limits to further reductions in diastolic BP (Barnes et al., 1999; Solberg et al., 2004).

Most previous studies examining the relationship of BP and stress were focused on assessing the effects of high stress levels or conditions on BP response. The studies documented a generally inconsistent increase in systolic BP and inconsistent changes in diastolic BP in response to stress. In this study, neither current nor perceived stress over the past month were correlated with either post-meditation systolic or diastolic BP. The findings were similar to some studies (Fauvel et al.; 2003; Kang et al., 2004; Lindquist et al., 1997), but different from most earlier studies (Carroll et al., 2001; Carroll et al., 2003; Hjortskov et al., 2004; Matthews et al., 2001; Sloan et al., 1996; Vrijkotte et al., 2000; Weinrich et al., 2000).

As noted in Tables 4−6 (p. 45, 52, and 58, respectively), there were inconsistent findings throughout the literature with respect to the effects of meditation on stress, BP, or HRV. Some studies employing meditators reported LF power increased, HF power increased, or both, from baseline to meditation period (see Table 5, p. 52) (Cysarz &

Bussing, 2005; Matzner, 2003; Peng et al., 1999; Peng et al., 2004). Only one study showed a decrease in HF power during the meditation period (Cysarz & Bussing, 2005). However, it is difficult to compare the results in this study with other studies reviewed because of differences in HRV measurements and research design. The previous studies compared HRV from baseline to meditation period. However, this study examined HRV only during the meditation period and compared it with the normal range of HRV according to norms established by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrotophysiology (1996) (see Table 1, p. 17). In this study, it was shown that participants had normal ranges of LF power and HF power of HRV. The findings of this study do provide additional information which may contribute to future understanding of the relationship between meditation and HRV.

While there was a statistically significant correlation between length of total meditation practice and perceived current stress, ANCOVA showed that meditation practice in terms of length, frequency, and session duration of practice failed to predict stress levels as measured by perceived current stress and PSS in this study. This result is in contrast with most previous studies reviewed using both meditators and non-meditators (Astin, 1997; Chang, et al., 2004; Goleman & Schawartz, 1976; Shapiro et al., 1998; Waelde et al., 2004). However, this finding is consistent with Robinson et al.'s findings (2003), in which perceived stress measured by the 10-item version of Perceived Stress Scale (PSS-10) was not decreased following meditation in a non-meditator sample.

ANCOVA also failed to predict BP and HRV by meditation practice. These findings are in contrast with most previous studies using both meditators and non-meditators (Barnes et al., 1999; Barnes et al., 2001; Barnes et al., 2004; Cysarz & Bussing, 2005; Matzner, 2003; Murata et al., 2004; Peng et al., 1999; Peng et al., 2004; Sudsuang et al., 1990; Takahashi et al., 2005; Wallace et al., 1983). However, this finding is consistent with Solberg et al.'s study (2004), in which diastolic BP was not changed from baseline to post-meditation.

Overall there were no statistically significant relationships among meditation practice, perceived stress, and ANS activity assessed through BP and HRV in this sample of meditators, with the exception of an inverse relationship between total length of meditation practice and perceived current stress. Thus, the hypothesized relationships in the research model (see Figure 5, p. 27) were not supported. The following discussion explores situations affecting the testing of the research hypotheses, which could have contributed to these results.

The sample was comprised of people who were practicing meditation within a spiritual community. While this sample of convenience gave the researcher ready access to a population of meditators, there may have been unintended consequences in terms of study outcomes. The practice of meditation within a spiritual context focuses on moment-to-moment awareness with multiple opportunities to practice this awareness (breathing practice, walking practice and so on). Thus, those who use meditation within a spiritual tradition are aware of life itself as a meditative opportunity, a life in which a meditative state is present from moment to moment and not isolated to the interval of sitting practice. The way in which meditation practice was measured in this study did not address or assess either the extent of meditation practice or the maintenance of mindfulness outside of sitting meditation. This is a particular feature among those who practice meditation within a spiritual tradition, in contrast to those who may practice sitting meditation as a discrete event designed to manage stress. The latter view of meditation practice informed the assessment of meditation practice in this study. It is possible that a more comprehensive assessment of "meditation practice" could have yielded different results, particularly with respect to the physiological effects of "meditation."

Research procedures were designed to minimize stress to participants during data collection. Most participants did indicate that at the moment of data collection, they felt calm and relaxed. However, it is possible that the physiological results obtained reflected a physiological response to the process of being monitored during meditation. Such a response would likely include activation of the SNS, and may have obscured the measurement of the usual physiological state during meditation. While the meditation interval was increased following the pilot study in order to address this concern, these effects may have persisted for a longer time than expected.

It is also possible that the stress measures were not sensitive enough or did not differentiate stress levels with sufficient precision in this sample of meditators, particularly given that they were meditators within a spiritual tradition. Future qualitative research may be needed to clarify the lived experiences of stress in experienced meditators and to develop relevant theoretical models on which future instrument development could be based. The focus on mindfulness among spiritual meditators may also mean that the emphasis of assessment needs to be on the quality of level of mindfulness and on mindfulness self-efficacy; that is, the moment-to-moment ability to maintain a mindful state, rather than focusing on external events and the perception of those events as stressful.

Finally, though a power analysis was conducted, a medium effect size was used in the calculation. If meditating over a long period of time creates a steady physiological state, the actual measurable effect of meditating in long-term meditators may be minimal. With the large number of experienced meditators in this study, the effect of meditation might have been small rather than medium. If this is the case, the sample size was too small, thus creating the possibility of a Type II error; that is, differences might have existed but were undetectable.

Conclusions and Implications

The purpose of this study was to examine the relationships among perceived stress, BP, HRV and meditation practice in meditators. A research model of relationships among perceived stress, BP, HRV and meditation practice provided a framework for testing two research hypotheses: (1) perceived stress had a positive correlation with BP and LF power, and an inverse correlation with HF power in meditators; and (2) meditation practice had a negative correlation with perceived stress, BP, and LF power, and a positive correlation with HF power in meditators. This research model was tested using a cross-sectional descriptive correlational research design.

Analysis of the data from 71 participants did not provide statistical support for either of the research hypotheses, although there was a statistically significant inverse relationship between level of perceived current stress and length of total meditation practice indicating that the longer one practiced meditation, the lower the amount of perceived current stress. Additionally, the sample of meditators was found to have low stress levels, both at the moment of data collection and for the month prior to the study. Finally, mean systolic BP after meditation was significantly decreased when compared to the pre-meditation measurement.

A rigorous scientific investigation of the effectiveness of meditation practice has been performed, revealing the complexities of assessing physiological mechanisms and outcomes associated with meditation in meditators within a spiritual tradition. This study contributes to the collective body of literature regarding the effects of meditation on stress states and on BP and HRV, providing no support for discernable physiological effects.

Strengths and Limitations

The major strengths of this study included integrating Lazarus and Folkman's stress appraisal theory and the physiology of BP and HRV as well as possible meditation mechanisms in order to construct the research model. There have been no studies published using meditators to examine the effect of meditation practice on psychological stress, BP, and HRV concomitantly. Thus, this study may provide guidance for future studies of meditators or the process of meditation.

Certain limitations result from the sampling design. All participants who volunteered to participate and who were eligible and provided consent were included in the study; however, it was a sample of convenience. Extraneous variables may have been introduced as a result. In terms of generalizability, data are not available regarding the demographic characteristics of the target population of meditators in the United States and therefore, it is not possible to ascertain the representativeness of the study sample. Thus, generalizability of the findings is limited. Research design and procedures minimized threats to internal validity, though testing effects may have affected the measurement of physiological variables. As noted above, it is possible that the medium effect size used for the power analysis was an overestimate of the effect of meditation in this group of participants. If the sample size was too small, then it is possible that hypothesized relationships were present but undetected.

Recommendations

Based on the findings in this study, recommendations for future research are offered. Recommendations follow for nursing education and practice as well as theory development.

Recommendations for Future Research

Assuming that there are physiological mechanisms associated with meditation that were undetected in this study, research designed to ascertain those potentially subtle changes needs to be conducted. Longitudinal studies of people who are non-meditators, who are beginning meditators, and who sustain meditation over time should be conducted. Monitoring of physiological changes (BP and HRV) as well as changes in perceived stress levels should be included, while controlling for covariate factors such as gender, age and race. The effects of various quantities and extent of all meditation practices need to be assessed, as do level of mindfulness and mindfulness self-efficacy. Studies of experienced meditators should include continuous monitoring of physiological variables including both meditation and non-meditation intervals, to provide needed information about the physiological effects of meditation in experienced meditators. Additionally, researchers should study whether there are common physiological mechanisms involved across those who practice meditation for different purposes, including practice for stress reduction and practice within the context of a spiritual tradition. Finally, qualitative research may be helpful to clarify the lived experiences of stress in experienced meditators and to develop relevant theoretical models as well as instruments for assessing perceived stress in meditators. These studies would be fruitful in increasing our understanding of the physiological effects of meditation.

Recommendations for Nursing Education and Practice

While the physiological mechanisms associated with meditation were not clarified by this study, the sample of meditators was found to have low stress levels. Low stress levels may be associated with meditation practiced within a spiritual tradition. Other studies have indicated that the practice of meditation also lowers stress levels. Given the adverse health consequences associated with high stress levels and the absence of any known harmful effects of meditation, it is reasonable that information be provided to nursing students and patients regarding the findings of lower stress levels in meditators. This could occur when addressing strategies for health and wellness promotion.

Recommendations for Theory Development

This study did not specifically assess the relationships between healing outcomes (states of health and well-being) with meditation practice. Thus, the information gained from this study cannot directly contribute to the body of knowledge regarding healing outcomes. Theory development in the area of healing would need to incorporate relevant outcomes such as quality of life, sense of harmony, balance, well-being, and self-awareness. As noted previously, theoretical models specific to meditators need to be developed with specific attention given to features of meditation practice. Variables such as mindfulness self-efficacy should be also evaluated for inclusion. Additionally, qualitative data are needed to develop specific understanding of the meanings of stress in the lived experience of meditators.

Summary

This chapter provided conclusions and implications of results and addressed the strengths and limitations of this study. The chapter also offered recommendations for future research. Future research is needed to clearly elucidate the effects of meditation on psychological and physiological measurements, particularly in those experienced in meditation.

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APPENDIX A

IRB Approval Letters and Questionnaires Approval Letter

MCV Campus

Virginia Commonwealth University

Office of Research
Subjects Protection

Sanger Hall, 1-023
1101 East Marshall Street
P.O. Box 980568
Richmond, Virginia 23298-0568

804 828-0868
Fax: 804 827-1448
TDD: 1-800-828-1120

DATE: July 26, 2005

TO: Dorothy P. Gray, RN, PhD
Adult Health
Box 980567

FROM: John D. Roberts, MD
Vice-Chairperson, VCU IRB Panel A
Box 980568

RE: **VCU IRB #: 5058**
Title: Relationships among Stress, Blood Pressure, and Heart Rate Variability in Mediators

On July 25, 2005, the following research study was ***approved*** by expedited review according to 45 CFR 46.110 Category 4. This approval reflects the revisions received in the Office of Research Subjects Protection on July 21, 2005. This approval includes the following items reviewed by this Panel:

RESEARCH APPLICATION/PROPOSAL: None

PROTOCOL: Relationships among Stress, Blood Pressure, and Heart Rate Variability in Mediators (received 7/21/05)

CONSENT/ASSENT:
- Research Subject and Information and Consent Form (received 7/21/05; 3 pages)

ADDITIONAL DOCUMENTS:
- Survey Cover Letter (received 6/14/05)
- Advertisement Flyer (received 6/14/05)

This approval expires on June 30, 2006. Federal Regulations/VCU Policy and Procedures require continuing review prior to continuation of approval past that date. Continuing Review report forms will be mailed to you prior to the scheduled review.

This Institutional Review Board is in compliance with good clinical practices (GCP) as defined under the U.S. Food and Drug Administration (FDA) regulations and the International Conference on Harmonization (ICH) guidelines. Virginia Commonwealth University is approved by DHHS to conduct human subjects research under a Federal Wide Assurance #FWA00005287. **All correspondence related to this research study must include the IRB protocol number and the investigator's name(s) to assist us in locating your file. Please note that the CCHR number is no longer valid, if applicable.**

The Primary Reviewer assigned to your research study is John D. Wilson, PhD. If you have any questions, please contact Dr. Wilson at jdwilson@vcu.edu or 828-7225; or you may contact Stephan Hicks, IRB Coordinator, VCU Office of Research Subjects Protection, at hickssa2@vcu.edu or 828-9876.

Attachment – Terms of Approval

MCV Campus

Virginia Commonwealth University

Office of Research Subjects Protection
Office of Research

BioTech Research Park, Building One
800 East Leigh Street, Suite 111
P.O. Box 980568
Richmond, Virginia 23298-0568

804 828-0868
Fax: 804 827-1448
TDD: 1-800-828-1120

DATE: November 4, 2005

TO: Dorothy P. Gray, RN, PhD
Adult Health Nursing
Box 980567

FROM: William E. Smith, PharmD, MPH, PhD
Chairperson, VCU IRB Panel A
Box 980568

RE: **VCU IRB #: 5058**
Title: Relationships among Stress, Blood Pressure, and Heart Rate Variability in Mediators

On November 2, 2005, the changes to your research study were ***approved*** in accordance with 110 (b) (2). This approval includes the following items reviewed by this Panel:

PROTOCOL: Relationships among Stress, Blood Pressure, and Heart Rate Variability in Mediators (received 10/26/05)

ADDITIONAL DOCUMENTS:

- Advertisement Flyer (received 10/26/05)

As a reminder, the approval for this study expires on June 30, 2006. Federal Regulations/VCU Policy and Procedures require continuing review prior to continuation of approval past that date. Continuing Review report forms will be mailed to you prior to the scheduled review.

This Institutional Review Board is in compliance with good clinical practices (GCP) as defined under the U.S. Food and Drug Administration (FDA) regulations and the International Conference on Harmonization (ICH) guidelines. Virginia Commonwealth University is approved by DHHS to conduct human subjects research under a Federal Wide Assurance #FWA00005287. **All correspondence related to this research study must include the IRB protocol number and the investigator's name(s) to assist us in locating your file. Please note that the CCHR number is no longer valid, if applicable.**

The Primary Reviewer assigned to your research study is John D. Wilson, PhD. If you have any questions, please contact Dr. Wilson at jdwilson@vcu.edu or 828-7225; or you may contact Stephan Hicks, IRB Coordinator, VCU Office of Research Subjects Protection, at hickssa2@vcu.edu or 828-9876.

EKŌJI BUDDHIST SANGHA
OF RICHMOND

Dr. D. Patricia Gray
Adult Health Department
School of Nursing
Virginia Commonwealth University
1220 E. Broad Street
Richmond, Virginia 23298-0567

Dear Dr. Gray:

September 23 2005

I am writing to confirm that at our September 22 2005 meeting, the Board of Directors of Ekoji Buddhist Sangha read and approved Sangthong Terathongkum's research request .The board looked at the questionnaire and the data she planned to collect. We found that the questionnaire measured what the researcher needed to measure. The board did not have any recommendations for change.

Members of the board will notify all the members of the sangha to encourage them to participate.

Sincerely,

Lenore H. Gay

Lenore H. Gay
President, Board of Directors
Ekoji Buddhist Sangha

3411 GROVE AVE., RICHMOND, VIRGINIA 23221

APPENDIX B

Informed Consent

Research Subject Information and Consent Form

Title: Relationships among Stress, Blood Pressure and Heart Rate Variability in Meditators

VCU IRB Protocol Number: 5058

Principal Investigator: Dorothy P. Gray, R.N., PhD.

This consent form may contain words that you do not understand. Please ask the study staff to explain any words or information that you do not clearly understand. You may take home an unsigned copy of this consent form to think about or discuss with family or friends before making your decision.

Purpose of the Study

The purpose of this study is to examine the relationships among stress, blood pressure, and heart rate variability in meditators. You are being invited to participate in a research study because you are a meditator. If you decide to participate, you will be one of 71 persons who will be involved as a participant in this study.

Description of the Study and Your Involvement

Growing evidence indicates that psychological stress contributes to cardiovascular diseases. Psychological stress leads to increased heart rate and blood pressure as well as decreased heart rate variability. Heart rate variability, which is the small changes that occur in your heart beat to beat, has been shown to be related to an individual's level of stress and state of health. Meditation is one approach to stress management. This approach elicits a relaxation response, which can be accompanied by changes in heart rate, blood pressure, and heart rate variability. The findings of this study will provide preliminary data for future work focused on stress management using meditation approaches in order to reduce risk for cardiovascular diseases in the United States.

If you decide to be in this study, you will be asked to sign this consent form. In this study you will be involved for approximately 50 minutes. You will be asked to complete the meditation practice questionnaire having 7 questions, the Perceived Stress Scale having 11 questions, and a short demographic questionnaire. You will sit in a relaxed position in a quiet room for 5 minutes. Then, the researcher will measure your blood pressure using an automatic blood pressure device (two readings one minute apart). Next, electrodes (small pads) will be placed on your right shoulder, left ribs, and right lower abdomen in order to record your heart rhythm data. You will be asked to meditate for 30 minutes while heart rhythm data are recorded. Lastly, blood pressure will be recorded again two readings one minute apart, and the electrodes will be removed.

Risks and Discomforts

There are minimal risks associated with the study. You may experience slight discomfort during the recording of blood pressure and heart rhythm data.
The survey in this study also includes questions that are personal. This may possibly make you feel uncomfortable.

Benefits

This is not a treatment study, and you are not expected to receive any direct medical benefits from your participation in the study. The information from this research study may lead to the development of techniques for stress management which may help others in the future.

Approved
JW / SH 7/25/05

Costs
There are no costs for participating in this study other than the time you will spend in the research study.

Payment for Participation
You will not be paid for your participation.

Alternatives
Your alternative is to not participate in the study.

Confidentiality
We will not tell anyone the answers you give us; however, information from the study and the consent formed signed by you may be looked at or copied for research or legal purposes by Virginia Commonwealth University. Personal information about you might be shared with or copied by authorized officials of the Federal Food and Drug Administration, or the Department of Health and Human Services.

What we find from this study may be presented at meetings or published in papers; neither your name nor any personally identifying information will be used in these presentations or papers.

If an Injury Happens
Virginia Commonwealth University and the VCU Health System do not have a plan to give long-term care or money if you are injured because you are in this study.

If you are injured because of your participation in this study, please tell the study staff immediately. She will arrange for someone to care for you if it is needed.
Bills for such treatment may be sent to you or your insurance. Your health insurance company may or may not pay for taking care of injuries as a result of your participation in this study.

Voluntary Participation and Withdrawal
Your participation in this research study is entirely voluntary. You may decide to not participate in this study. If you choose to participate, you may freely withdraw from the study at any time without any penalty. You may also choose not to answer particular questions that are asked in the study. Your decision will not change your future medical care at VCU Health System. Your participation in this study may be stopped at any time by the investigator without your consent. The reasons might include:

- it is necessary for your health or safety;
- you have not followed study instructions;
- the investigator has stopped the study; or
- administrative reasons require your withdrawal.

Questions
In the future, you may have questions about your participation in this study. If you have any questions, contact:

Approved
JW / SH 7/25/05

Dorothy P. Gray, R.N., PhD
School of Nursing, Virginia Commonwealth University
1220 East Board Street
Richmond, VA 23298-0567
(804) 828-3320
Or
Sangthong Terathongkum, R.N., M.S.
School of Nursing, Virginia Commonwealth University
1220 East Board Street
Richmond, VA 23298-0567
(804) 644-5815

If you have questions about your rights as a participant, you may contact:

Office of Research Subjects Protection
Virginia Commonwealth University
800 East Leigh Street, Suite 111
PO Box 980568
Richmond, VA 23298
(804) 828-0868

Consent
I have been given the chance to read this consent form carefully. I understand the information about this study. All of the questions that I wanted to ask about this study have been answered. My signature indicates that I am willing to participate in this research study.

....
Participant Name Printed Participant Signature Date

....
Signature of Person Conducting Informed Consent Discussion Date

....
Signature of Witness Date

....
Investigator Signature (If different from above) Date

Approved
JW / SH 7/25/05

APPENDIX C

Questionnaires

Dear Participant,

I am a graduate student in the VCU School of Nursing. In order to fulfill the requirements of the PhD program, I am conducting a research study designed to examine the relationships among stress, blood pressure, heart rate variability, and meditation practice. This questionnaire is part of a study designed to examine the relationships among stress, blood pressure, heart rate variability and meditation practice. The information that you give will be used to promote health and prevent diseases. You are being given this questionnaire by Virginia Commonwealth University and me. You may have filled out a questionnaire like this before, but it is important to me that you answer these questions again.

Do not write your name on this survey. An anonymous code will be assigned to your questionnaire. All of your answers are private. Nobody in your family or your friends will ever see your answers to these questions. I make this promise because I want to protect your privacy and because I hope that it will encourage you to answer honestly. Please think about each question carefully and answer truthfully.

Thank you for your help.
Sangthong Terathongkum, MS. PhD (c), RN
School of Nursing
Virginia Commonwealth University

Part I: Meditation Practice Questionnaire

Instruction. Please fill in the blank or check one answer for each question.

❶ How long have you practiced meditation (all forms, including your current form of meditation?

___________months

❷ What is your current form of meditation practice?

❑ Soto Zen

❑ Vipassana

❑ Pure Land

❑ Tibetan Karma Kagyu

❑ Other (Please specify)………………………………………………………

❸ How long have you practiced your current form of meditation?

___________months

❹ In an average week, how many days a week do you practice your current form of meditation

___________days

❺ How many times a day do you practice your current form of meditation?

____________times

❻ For each time of your practice, how long do you meditate?

____________minutes

❼ Have you ever practiced other forms of meditation?

❑ No

❑ Yes (Please specify) Type:…………………………………………………..

Duration of practice:………………………………Years

Part II: Perceived Stress Scale Questionnaire

Using the following scale, where 1 is a very low level of feeling stressed, and 10 is a very high level of feeling stressed, how stressed are you feeling right now?

One____Ten

1 2 3 4 5 6 7 8 9 10

Instruction. The questions in this scale ask you about your feelings and thoughts during the last month. In each case, you will be asked to indicate by circling how often you felt or thought a certain way.

0 = Never, 1 = Almost Never, 2 = Sometimes, 3 = Fairly Often, 4 = Very Often

1. In the last month, how often have you been upset because of something that happened unexpectedly?	0	1	2	3	4
2. In the last month, how often have you felt that you were unable to control the important things in your life?..................	0	1	2	3	4
3. In the last month, how often have you felt nervous and stressed?..	0	1	2	3	4
4. In the last month, how often have you felt confident about your ability to handle your personal problems? …………….....	0	1	2	3	4
5. In the last month, how often have you felt that things were going your way? ………………………………………………	0	1	2	3	4
6. In the last month, how often have you found that you could not cope with all the things that you had to do? ………..	0	1	2	3	4
7. In the last month, how often have you been able to control irritations in your life? ……………………………………...	0	1	2	3	4
8. In the last month, how often have you felt that you were on top of things? ………………………………………………	0	1	2	3	4
9. In the last month, how often have you been angered because of things that were outside of your control? …………	0	1	2	3	4
10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them? ….	0	1	2	3	4

Part III: Demographic information

Instruction. Please fill in the blank or check one answer for each question.

❶ What is your gender?

❑ Female

❑ Male

❷ How old are you? ……………Years

❸ What is your race?

❑ African American/Black

❑ Caucasian/ White

❑ Hispanic

❑ Asian/ Pacific Islander

❑ Other (Please specify) …………………………………………………………..

❹ What is your religion?

❑ Buddhism

❑ Christian

❑ Islam

❑ Other (Please specify)…………………………………………………………

❺ What is the last education level that you completed?

❑ Some high school

❑ High school graduate

❑ Some college

❑ College graduate

❑ Graduate degree

❑ Other (Please specify)………………………………………………………

❻ Do you regularly take any medicine?

❑ No

❑ Yes (Please specify)…………………………………………………………..

APPENDIX D

Specification of Blood Pressure Equipment

Specification of Omron Model HEM-705CP Automatic Sphygmomanometer

Model	HEM-705CP
Display	LCD digital display
Measurement range	Pressure 0 to 299 mmHg Pulse 40 to 180 mmHg
Accuracy/Calibration	Pressure ± 4 mmHg Pulse ± 5% of reading
Inflation	Automatic by electric pump
Deflation	Active electronic control valve
Rapid pressure release	Active electronic control valve
Pressure detection	Capacitive pressure sensor
Measurement method	Oscillometric method
Pulse wave detection	Capacitive pressure sensor
Power source	4 “AA” batteries or AC adapter
Battery life	Approximately 300 uses
Operating temperatures/humidity	50°F to 104°F (10°C to 60°C) 30 to 85% RH maximum
Main unit weight	Approximately 13.4 oz (380g) not including batteries
Main unit dimensions	Approximately 4 ½” (l) x 7” (w) x 2 4/5” (h) (115 mm x 177 mm x 71 mm)
Cuff dimensions	Approximately 5 ½” x 19” (140 mm x 480 mm)
Cuff circumference	Fits arm circumference 9” to 13”
Accessories	Arm cuff, printer unit, paper roll, instructional manual

Source: Omron Instructional Manual, 2001

APPENDIX E

Specification of the Log-a-Rhythm model 100

Heart Rate Variability using Log-a Rhythm Model 100

Log-a-Rhythm® Models 100 records consecutive heart beat intervals and use these to calculate heart rate over time. The intervals are stored as computer data files that can be analyzed by user-provided software or by Log-a-Rhythm® Heart Rate Analysis software.

The Log-a-Rhythm® Model 100 System Consists of:

Signal Acquisition Unit contains a two channel amplifier, a microprocessor, and memory. On its external panel are: a socket for connecting the patient cable, a socket for connecting a serial cable, on and off switches, and an LED. The battery compartment, accessible by removing the cover, fits two standard 9 volt batteries.

The Patient Cable may be either a standard 3 lead or a standard 5 lead ECG cable. Color coding of the 5 snap-type female connectors is according to ANSI/AAMI standards (EC-11 1991). The DIN type connector plugs into the mating socket on the Log-a-Rhythm® Signal Acquisition Unit.

Communication and Display Software links the Log-a-Rhythm® Signal Acquisition Unit with a computer. It configures the data collection mode, sets the Log-a-Rhythm® clock, and transfers data from the Log-a-Rhythm® Signal Acquisition Unit to the computer. It is also used for displaying and printing results.

Recording Heart Data

1. To set Log-a-Rhythm® Signal Acquisition Unit for recording heart data, communication cable using the 9-pin connector provided is attached to the serial port of a computer. One end of the phone plug is inserted into the connector and the other end into the mating jack of the Log-a-Rhythm® Signal Acquisition Unit. Start the Log-a -Rhythm

program, choose configure menu, and follow commands until you see the message 'Settings Sent - You may use Log-a-Rhythm®.'

2. Before attaching the patient cable to the Signal Acquisition Unit, detach the serial cable from the unit. Locate the round five pin socket on the unit. Then, locate five electrodes on a patient. The accuracy of Log-a-Rhythm® depends upon the proper placement of electrodes. For best beat detection, use high quality electrodes and well prepared skin. Lowest noise is generally achieved by placing electrodes over bony areas. There are three types of cables: Type 1, the standard five-lead Flat Ribbon Cable; Type 2, a five-lead cable with Removable Leads; and Type 3, a three-lead cable. This study uses type 2, rhythm strip on demand, which white lead is right arm and red lead is left leg (Lead II). The white and red leads always use channel 1. Brown is ground, and channel 2 uses the black and green leads. Thus, the black electrode is placed on the lower left abdomen near the red lead; and the green lead is attached on the right shoulder near the white lead. Brown, which is attached on right lower abdomen, is ground.

3. Start to record heart data by pushing the red button on the Signal Acquisition Unit. When the unit starts you will hear a series of six short beeps. To stop or pause signal acquisition, push and hold the black button, then push the red button. Next release the black button and the red button.

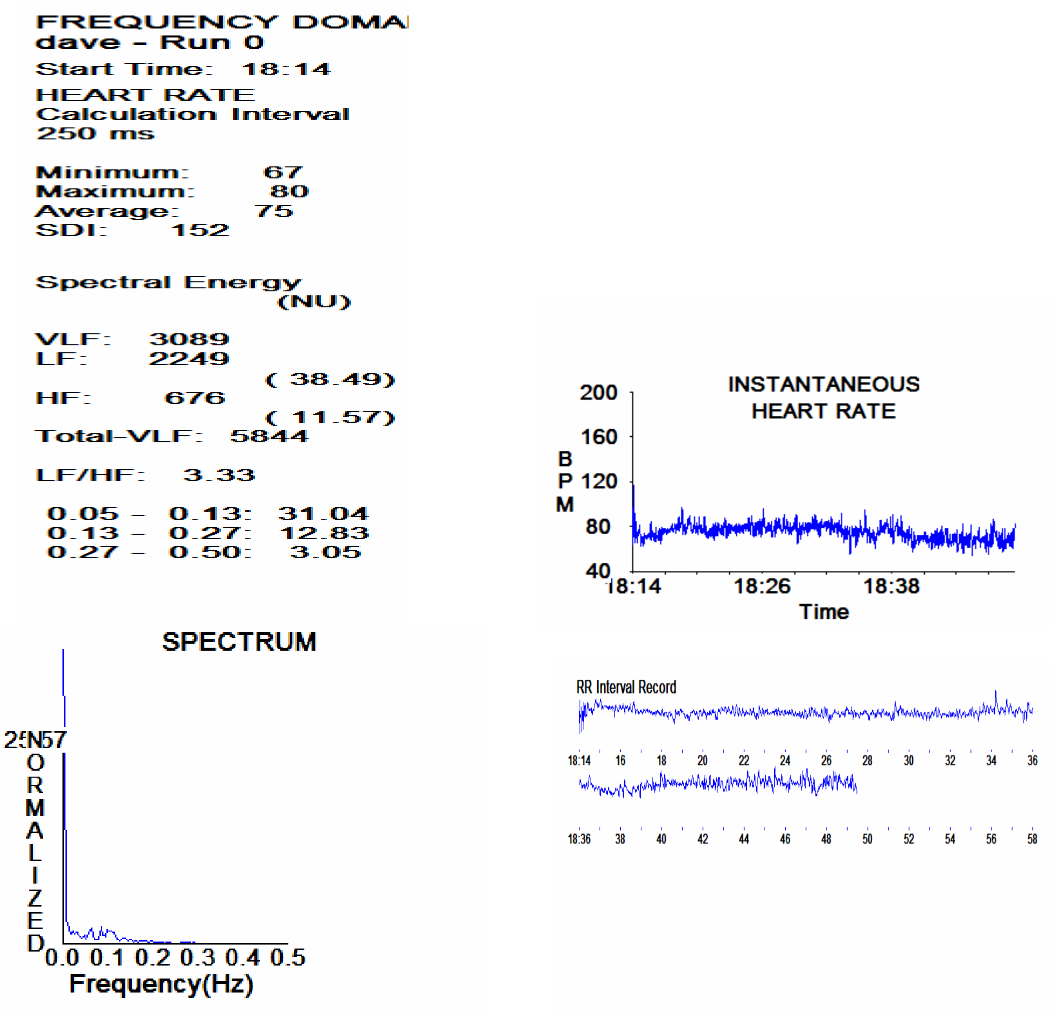
If you have selected manual gain adjustment the Signal Acquisition Unit will start signal acquisition as soon as it is turned on. If automatic gain adjustment has been selected, a gain adjustment period will occur prior to the start of signal acquisition. During this adjustment period you will hear occasional beeps, then, if gain adjustment is successful, a few beeps at the rate the heart is beating. After successful gain adjustment, you will hear a short beep and then the unit will begin the data acquisition. You should now see the LED flash briefly for each heart beat.

If you continue to hear sporadic beeping for an extended period of time or the unit becomes silent and you do not see the LED flash, you should stop the Signal Acquisition Unit and check the electrode placement.

Uploading and Analyzing Heart Rate Data

Detach the patient cable from the Log-a-Rhythm® Signal Acquisition Unit and connect the communication cable from it to the computer. Then, run the Log-a-Rhythm program. Select the 'Log-a-Rhythm®/Upload' option and click the 'Connect to Log-a-Rhythm®' button. Follow the demands until you see 'Download Successful'. Click ‘OK’.

The Time Domain Analysis Screen will appear automatically when you open an R-R interval data file or Upload R-R interval data from Log-a-Rhythm®. To view the frequency domain analysis, which power spectrum estimation uses the Fast Fourier Technique, select the analysis/frequency domain option. If the data contains artifacts, you may select an artifact free segment. Then, click on the 'Report/Create' menu option. The reports are displayed as diagrams and numbers. The example for frequency domain analysis is shown below:



Specification

General:

Completely Solid State

Push Button Event Signaling Option

Portable - can be carried in a waist pouch

Automatic adjustment of recording parameters based on signal characteristics

AECG device type 3.

Channels	1 or 2
Cable	Standard Ambulatory ECG
ECG Amplifier : Sampling Resolution ECG Resolution Gain CMRR Input Resistance Input Bias Current Bandwidth Defibrillator Protection	 4 ms. * 40 mV Automatic gain control. Variable from 600 to 6000 100 dB 10 GW 6 nA 0.05 Hz to 50 Hz 24 V maximum input
Cardiotach: Range Resolution Tall T Wave Rejection	 0 to 230 BPM (R-R interval > 260 ms.) * 4 ms. interval * R - T interval <= 260 ms.
Heart Rate Trend: Range	up to 36 hours (depending upon heart rate) 0 to 230 BPM *
Input/Output Serial Cable	 RJ-11 phone jack to DB9 or DB25 connector
Error Condition Signals: High Rate Low Rate Asystole Lead Off Low Battery Signal Mode	 > 200 BPM < 29 BPM R to R interval > 2 sec. Offset potential > R wave peak for more than 1 second Vcc < 4.5V LED & Internal Beeper
Mechanical: Size Weight Switches	 3.74" x 6.288" x 1.33" (9.5 cm x 16.0 cm c 3.4 cm.) 12 oz. (340 gm.) - including batteries and case Two push button (On/Event Signal and Off)
Power Requirements: Batteries Operating Time	 Two 9 volt (Rechargeable recommended) 33 hours
Recording Time: Beat Mode - Single Channel Rhythm Mode - Single Channel Rhythm Mode - Two Channels	 20 hours (100 bpm) - 34 hours (60 bpm) 8 - 20 minutes 4 - 10 minutes
Analysis and display time: Data Uploading Rhythm strip	 less than 2 1/2 minutes (maximum record) 10-20 sec (Pentium)

Resource: Log-a-Rhythm® Heart Rate Analysis software (Nian-Crae, 2003).

VITA

Sangthong Terathongkum was born on May 26, 1964 in Bangkok, Thailand, and is a citizen of Thailand. She graduated high school from Sainumpueng School in Bangkok, Thailand, in 1982. She received a Bachelor of Science in Nursing and Midwifery from Mahidol University, Thailand in 1986, a Master of Science in Human Reproduction and Population Planning from Mahidol University, Thailand in 1995, and a Bachelor of Law from Sukhothaithammathirat University, Thailand in 2002. She was employed as a registered nurse at the Department of Nursing, Faculty of Medicine, Mahidol University, Thailand between 1986 and 1997. She has served as a full-time academic nursing faculty at the same department since 1997 and received a full scholarship from her department to study for the doctoral degree at the School of Nursing, Virginia Commonwealth University, USA between 2001 and 2006.